HONEY BEE HABITAT AT THE UNIVERSITY OF ILLINOIS CAMPUS

BY

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THESIS

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ABSTRACT

There has been a decrease in the numbers of pollinators, and pollinator refuges are needed to confront risks associated with the effects brought about by the pollinator shortage. This research studies the potential of using current No-Mow Zones and prairie zones at the University of Illinois as pollinator refuges and proposes new possible sites to form a network of pollinator habitats on campus. The ecological approach considers human systems and natural systems to be integral and mutually impacting. The project consists of three parts. The first part is research on existing No-Mow Zones and prairie zones on campus to explore the possibility of developing those areas into pollinator habitats. The second part is the selection of potential sites for new pollinator habitats on the University of Illinois campus. The third part applies my findings to a series of site-specific proposals and proposes habitat design guidelines. This thesis envisions the changes in campus landscape response to the decrease in pollinators and proposes new pollinator habitat sites.

ACKNOWLEDGEMENTS

This work would have been impossible without the valuable support and feedback of the faculty at the Landscape Architecture Department at the University of Illinois, Urbana-Champaign. I offer my thanks to everyone who has contributed toward the completion of this work, especially Professor David Kovacic, my chair and advisor, Professor Amita Sinha, and Professor Carol Emmerling. And I appreciated support from my family and my friends.

TABLE OF CONTENTS

CHAPTER 1: INTRODUCTION

1.1 Background Information

The non-native European honey bee (Apis mellifera) is the most important crop pollinator in the United States. “It is estimated that about one third of all plants or plant products eaten by humans are directly or indirectly dependent on bee pollination,” (Bradbear, 2009). However, the number of bees has decreased dramatically in the past fifty years. The phenomenon of decreasing bee numbers is known as colony collapse disorder. Colony collapse disorder (CCD) is a phenomenon in which worker bees from a beehive or European honey bee colony abruptly disappear (Benjamin, 2007). The main factors behind the decrease are reduced amounts of food, reduced habitat, infection from mites and beetles, and pesticides.

In Illinois pollinator habitat loss is a result of agricultural and urban development. Illinois was once known as the Prairie State because of the biologically rich grassland that covered about 60% of the Illinois landscape. Today, more than 99% of the original prairie is gone, accompanied by the loss of pollinator habitats (Jeffords, 2014). Bees have decreased in number over the last few centuries because of vanishing nesting places and food resources in the managed agricultural landscape.

1.2 Conceptual Framework

Since 2007, the Facilities & Services on the University of Illinois campus has experimented with No-Mow Zones and prairie zones on small pieces of land to reduce fuel consumption and carbon emissions produced by mowing lawns. The location and images of No-Mow Zones and prairie zones is shown on the map (Figure 1, 2) and photos below (Figure 3). Inadvertently they

also set up an experiment where I was able to evaluate, the value of No-Mow Zones and prairie zones as potential honey bee habitat refuges.

The conceptual framework of this study is based on the use of existing campus No-Mow Zones and prairie restorations as potential bee habitats. To further increase bee habitat on the University of Illinois campus I have designed a network of bee habitats.

Plantings that resemble natural native plant communities in species composition will be more sustainable and are also the most likely to resist pests, disease, and weed epidemics and thus will confer the most pollinator benefits over time. Therefore, I conducted surveys of No-Mow Zones and prairie restorations on or near campus to evaluate the species composition that can serve as a guideline for new habitat construction.

The research methods underlying this project include a literature review and the collection of local data from diverse local agencies and websites. Plant information was collected from surveys of five plots of existing No-Mow Zones. Plant information for four plots in Meadowbrook Park was provided by Professor David Kovacic. The data was analyzed and the results were used to evaluate the potential of the sites to serve as honeybee habitats on the University of Illinois campus. Existing campus land use was analyzed using GIS and social behavior maps.

The method of bee habitat restoration design was to confirm the existing habitat condition and take appropriate measures to enhance bee habitats. With regard to plants already at the sites, the focus was to determine if those plant species could provide enough food for bees during the growing season and if need be to enhance habitats based on bee requirements. With regard to developing new bee habitats, habitat construction can take the form of demonstration gardens that strive to develop a community of herbaceous plants. Such a community mimics the local

native ecosystem in terms of plant density and diversity and species composition. Such a site location should be chosen based on the requirements for bee habitats.

1.3 Significance

In response to the decline in the number of honeybees, developing new bee habitats on campus would be beneficial. The Facilities and Services department at the University of Illinois maintain No-Mow Zones and prairie zones on campus to lower maintenance costs and reduce gasoline usage accompanied by pollution abatement. However, these areas could also be enhanced to serve as a honey bee refuges and as a honey bee conservation demonstration project for students.

Figure 1. Location of University of Illinois at Urbana-Champaign.

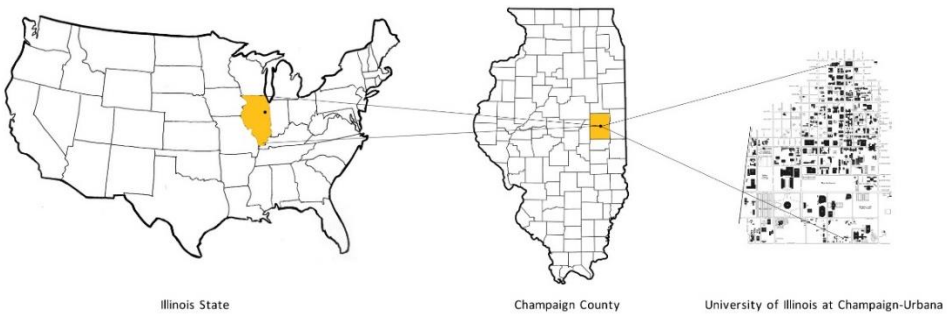
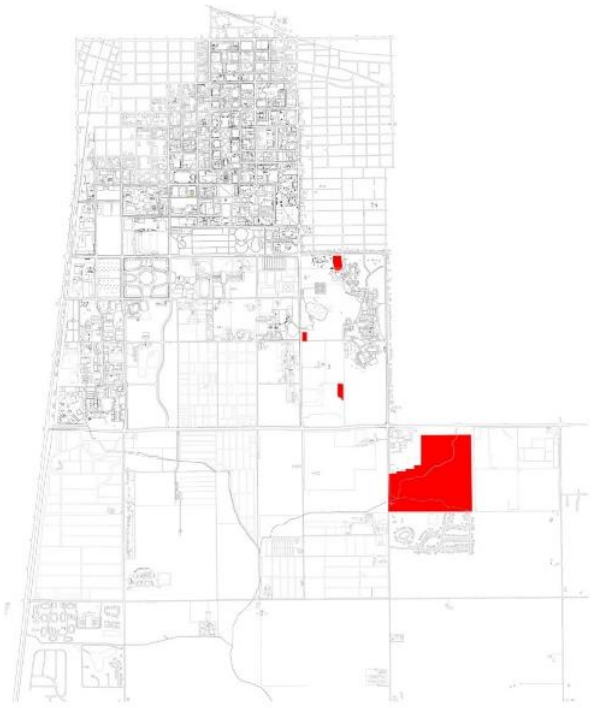
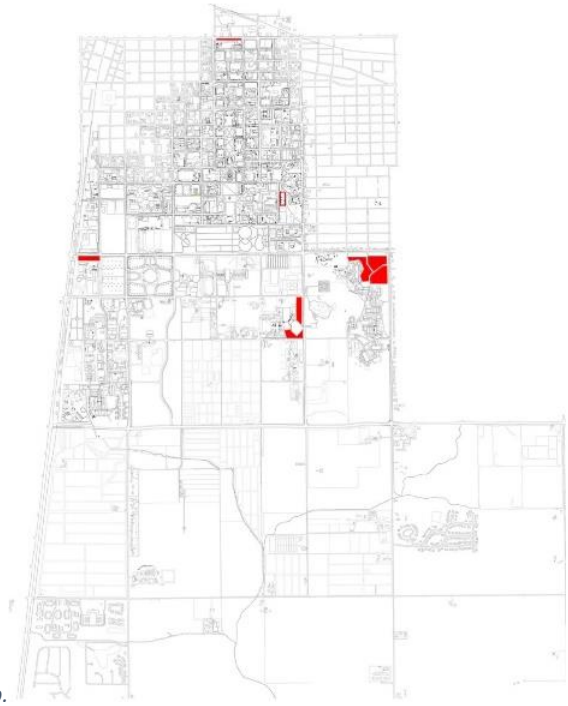


Figure 2. a. Existing No-Mow Zones Location.

b. Existing Prairie Zones Location.



a.



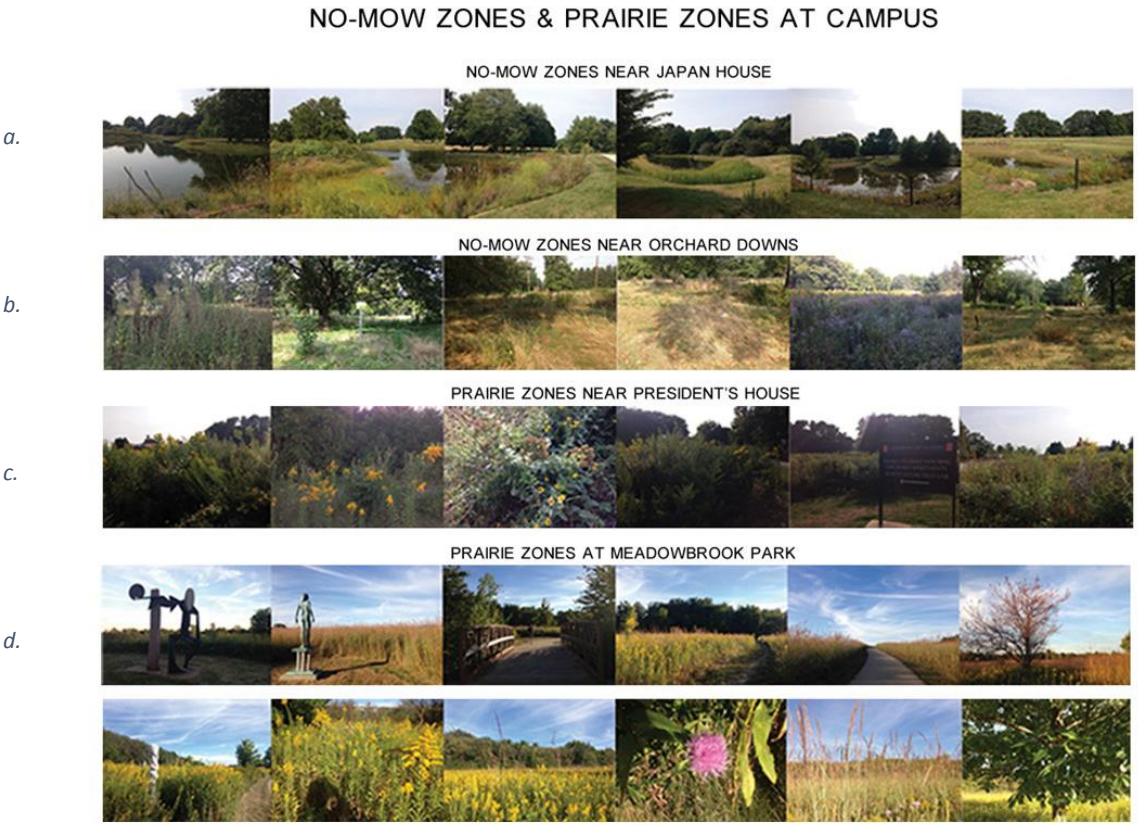
b.

Figure 3. a. Photos of No-Mow Zones near Japan House.

b. Photos of No-Mow Zones near Orchard Downs.

c. Photos of Prairie Zones near President's House.

d. Photos of Prairie Zones at Meadowbrook Park.



CHAPTER 2: LITERATURE REVIEW

The following review of research concerning bee habitat requirements with regard to plant species and site physical conditions includes 1) topical background; 2) related theories; 3) related projects.

2.1 Related Theories

2.1.1 Requirements for pollinator habitat

"In general, pollinator habitat would be, drought-tolerant, pesticide free, and, ideally, contain at least 70 percent native plants and the plants must be appealing to bees and other pollinators," (Shepherd 2008). Based on Westrich's work, "Habitat requirements of central European bees and the problems of partial habitats," and Mader's work, "Attracting native pollinators," the requirements of bee habitats are summarized as below:

a) Aspect: In general, areas of level ground, with full sun throughout the day, and good air circulation offer the most flexibility (Westrich, 1996).

b) Sun exposure: Since some plants require full sun or shaded conditions to thrive, the planting design should allow for plants to remain in their preferred condition as the habitat matures. Generally, plants will flower more, and thus provide greater amounts of nectar and pollen, when they receive more sunlight than when they are fully shaded.

c) Soil characteristics: Soil type is also an important consideration when selecting a site, with some plants favoring particular soil textures such as sand, silt, clay, or loam. Drainage, salinity, pH, organic content, bulk density, and compaction are some of the other factors that will influence plant establishment.

d) Adjacent land use: Along with exposure and soil conditions, adjacent plant communities and existing land use activities should be considered. For example even if weeds are

eliminated prior to planting, the presence of invasive plants adjacent to the restored habitat may result in a persistent problem that requires ongoing management.

e) Size and shape: The larger the planting area, the greater the potential benefit to pollinator species. An area considered for enhancement should be at least one half acre area in size, with a size of two acres providing even greater benefits. With herbaceous plantings, large, square planting blocks will minimize the edge around the enhancement site and thus reduce susceptibility to invasion by weeds surrounding the perimeter (Mader, 2011).

2.1.2 Requirements for plants of pollinator habitat

The main requirement for plants of bee habitat is that flowers should be available throughout the entire growing season. For honeybees, flowers are supposed to support nectar or pollen as food resource ranging from March to November (Lovell, 1918). A special effort should be made to conserve very early and very late blooming plants, to provide a food source for bees after hibernation and to help bees build up their energy reserves before entering winter hibernation (Westrich, 1996).

a) Diversity

Plant diversity is critical for bee habitat. "It is desirable to include a diversity of plants with different flower colors, sizes and shapes as well as varying plant heights and growth habits to encourage the greatest numbers and diversity of pollinators,"(Sota, 2014). Researchers in California have found that when eight or more species of plants with different blooming times are grouped together at a single site, they tend to attract a significantly greater abundance and diversity of bee species, and at least three different pollinator plants within each of three blooming periods are recommended (Wojcik, 2008).

Under this plan at least nine blooming plants should be established in pollinator enhancement sites.

b) Plant clusters

It is suggested that clump-plantings of at least three foot by three foot blocks of an individual species (that form a solid block of color when in flower) are more attractive to pollinators than when a species is widely and randomly dispersed in smaller clumps. Even larger single-species clumps (e.g., a single species cluster of perennials or shrubs more than 25 square feet in size) may be even more ideal for attracting pollinators and providing efficient foraging (NRCS, 2013).

c) Native or non-native

The North American Pollinator Potection Campaign discusses the selection of native plants vs. non-native plants. "Native plants are adapted to the local climate and soil conditions where they naturally occur. Native plants are advantageous because they generally require less fertilizer and pesticides for maintenance, require less water, provide permanent shelter and food for wildlife, and promote local native biological diversity. Conversely, non-native plants may become invasive and colonize new regions at the expense of diverse native plant communities. Mixtures of native and non-native plants are also possible, so long as non-native species are naturalized and not invasive," (Ley, 2011). The description above gives a clear illustration of the pros and cons of native and non-native plant selection.

d) Inclusion of non-flowering plants

Based on "Selecting plants for pollinators - a regional guide for farmers, land managers and gardeners in the prairie parkland," herbaceous plantings should include at least one

native bunch grass or sedge adapted to the site in addition to the three or more forbs from each of the three bloom-periods. The combination of grasses and forbs forms a tight living mass that will resist weed colonization. Grasses are also essential to produce conditions suitable for burning, if that is part of the long-term management plan (Ley, 2011).

e) Seed mix use:

The 2012 General Conservation Reserve Program provides the following guidelines, which apply to every seed mix used: 1) At least three plants from each grouping (early, mid, or late season blooming) will be included in the mix; 2) As many different plants as possible from each group will be included in the mix. Increasing the diversity of plants will increase the variety and number of pollinators that use the planted area; 3) The percentage

of each plant in the mix may vary based on the total number of plants used (NRCS, 2013).

2.2 Related Projects:

The Farm Service Agency (FSA) collaborated with pollinator experts and other conservation partners to develop, Conservation Reserve Program Job Sheet CP42-Pollinator Habitat, to help enhance and restore habitat for ecologically and economically significant pollinator species. CP-42 defines pollinator habitats as "areas of permanent vegetation located in an agricultural landscape: field edges, field middles, odd corners, or virtually any location that is suited for pollinator habitat. Vegetation consists of acceptable herbaceous and woody plants."

This document provides a four-step approach to pollinator conservation: 1) Advice on recognizing existing pollinator habitat, including existing plant composition and nesting and overwintering sites; 2) Steps to protect pollinators and existing habitat, including minimizing pesticide use; minimizing the impact of mowing, haying, burning, and grazing; protecting ground nesting bees; protecting tunnel-nesting bees; 3) Methods to further enhance or restore habitat for pollinators, including site selection considering aspect, sun exposure, soil characteristics, adjacent land use; using marginal land; size and shape; habitat design including landscape considerations, diverse plantings, plant diversity and bloom time; inclusion of grasses; plant selection and seed sources including native plants, seed sources, transplants, avoid nuisance plants applications for non-native plant materials; creating artificial nest sites.4) Managing habitat for the benefit of a diverse pollinator community (NRCS, 2012).

2.3 Study Concepts

The method of bee habitats restoration was to study the existing situation and to take appropriate measures to enhance bee habitat. For existing plant composition, the focus is to determine whether the species could provide a sufficient food source for bees throughout the growing season and to enhance habitats based on plant species requirements. For developing new bee habitats, habitat construction would take the form of demonstration gardens which strive to create an herbaceous plant community that mimics the local native ecosystem assemblage of plant density and diversity and to choose site locations based on bee habitat requirements.

CHAPTER 3: SPECIES RESEARCH – EXISTING HABITAT

3.1 Methodology

3.1.1 Data Collection

This section draws primarily on an examination of the species which cover existing no-mow and prairie zones on campus. Regarding No-Mow Zones, five plots within two sites were selected. One site was located at the corner of West Florida Avenue and South Race Street, the other site north of the Veterinary Medicine building on Lincoln Avenue. These five plots were similar in size (1-2 acres) and similar visual species composition. To sample these plots for species and coverage, I used the Illinois Natural History Survey methodology for plant cover assessment used in the Illinois Critical Trends Analysis (CTA) program. I placed a 100 meter tape straight through the middle of each plot, making sure there was a 20 meter buffer zone between the plot boundary and the measurement line.

A 0.5 m $\times$ 0.5m square quadrat was placed every 5 meters along the two sides of the transect line and each quadrat was assessed visually for cover and species. The document defines the species coverage of each quadrant using coverage classes as A=<1%, B=1-5%, C=5-25%, D=25-50%, E=50-75%, F=75-95%, G=95-100%. Figure 4 shows the sampling techniques applied in No-Mow Zones. Figure 5 shows the aerial photographs of No-Mow Zones and transect locations.

Regarding prairie zones, Meadowbrook Park included 80 acres of recreational Illinois tallgrass prairie. It was a good example of the existing prairie zone on or near campus. Figure 6 shows the Meadowbrook Park site plan. Figure 7 shows the aerial photographs of Meadowbrook Park and transect locations. Coverage data of Meadowbrook Park was collected by the LA450 graduate class in September 2006. The sampling method was the same as for all No-Mow Zones.

Figure 4. Photographs of Sampling Techniques.

Figure 5. Aerial Photographs of No-Mow Zones and Transect Locations.

Five transects in No-Mow Zones. For each transect, A and B represent stake 1 and 2 respectively. The number 1, 2, 3, 4 and 5 represent No-Mow Zones transect 1, 2, 3, 4 and 5 respectively.

Figure 6. Meadowbrook Park Site Plan.

Located in south Urbana along Windsor Road and Race Street, Meadowbrook Park features an 80 acres of recreated Illinois tallgrass prairie.

Figure 7. Aerial Photographs of Meadowbrook Park and Transect Locations.

Four transects in Meadowbrook Park. For each transect, A and B represent stake 1 and 2 respectively. The number 1, 2, 3 and 4 represent Meadowbrook Park transect 1, 2, 3 and 4 respectively.

3.1.2 Ecological Indices – Methodology

"Ecological indices are used to provide summary information about a particular aspect of ecosystem behavior," (Fath, 2004). Here we investigate four indices: species similarity, species richness, species diversity and Floristic Quality Assessment (FQA). Species similarity is used to determine the similarity of species among plant communities (Colwell, 2009). Here the species similarity index was used to determine the similarity of plant species among transects, within each plant community (No-Mow Zones or Meadowbrook Park).

Species diversity indices combine both species richness and species abundance in a single index (Odum, 1993). Here species richness is the number of different species occurring in each transect, species abundance is the relative coverage of the species. The great the number of species in a transect and the greater the coverage of each species, the greater the diversity of the transect.

Floristic Quality Assessment (FQA) is proposed as a method to assess floristic integrity in Illinois. FQA summarizes several parameters of plant communities, including a weighted measure of species richness (FQI), a mean coefficient of conservatism (C), guild diversity, proportion of adventive taxa, wetness characteristics, relative importance of native species, physiognomic characteristics, and rare species. The coefficient of conservatism (C) is an integer from 0 to 10 assigned to each taxon of the Illinois flora and used in calculating the floristic quality index. Each value reflects an estimate of a plant's tendency to be restricted to "natural areas". Here, 0 is the lowest ecological value, and 10 is the highest. All non-native species were assigned asterisks (*) and are treated as 0s in the calculations for site indices (Taft, 1997).

Statistical analyses. A two-tailed t-test assuming unequal variances was used to compare ecological indices. An alpha level of 0.05 or less was used to test for significant differences in

populations. Excel's statistical analysis tools were used to perform the analyses (Microsoft, 2010).

3.2 Results of Species Coverage

Results of coverage data are gathered in Tables 1-5 (No-Mow Zones), and Tables 6-9 (Tallgrass prairie). These tables provide a clear illustration of species richness, average vegetation coverage, and plant diversity in existing No-Mow Zones and prairie zones on campus.

Table 1. Plant Species Coverage in No-Mow Zone 1.

There were 24 species found collectively on the five No-Mow Zone transect. No-Mow Zone 1 contained 9 species, the dominant species were Canadian Wild Rye (60% frequency, 10% coverage), Common Dandelion (65% frequency, 11% coverage), Kentucky Bluegrass (95% frequency, 32% coverage), Switchgrass (75% frequency, 22% coverage).

Site: N-M-1
Date: 10/10/13

GPS: 40°5'44"N 88°12'41"W
Stake 1: 40°05'51.16"N 88°12'37.21"W
Stake 2: 40°05'49.59"N 88°12'40.95"W

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Frequency (%)	Percentage (%)
Bald Cypress																					0	0
Canadian Wild Rye	C	D	E	C	C	C		B	C			B	B	C				B			60	10
Common Dandelion	C	D	C		B	B		C	C	D	C	D				C	C		B		65	11
Common Hackberry																					0	0
Common Milk Weed																					0	0
Common Morning Glory	C																				5	1
Curly Dock																					0	0
Eastern Red Cedar																					0	0
Field Nut Sedge																					0	0
Field Thistle																					0	0
Frost Aster												D									5	2
Garlic Mustard																					0	0
Japanese Honeysuckle																					0	0
Kentucky Blue Grass	F	F	D	B	B	C	F	A	A	F	B	B	D	F	F	C	A		B	B	95	32
Lamb's Quarters																					0	0
Northern Red Oak	F																				5	4
Norway Spruce																					0	0
Old field Goldenrod																					0	0
Pennsylvania Smartweed																					0	0
Pokeweed											C										5	1
Prairie Blazing Star																					0	0
Switchgrass	D	D	D				E		C	C	C	C		C	D	D	D	C	D	C	75	22
Western Ragweed								C						C				C			15	3
Yellow Wood Sorrel																					0	0

Percent Cover Classes:

A= <1%	C= 5-25%	E= 50-75%	G= 95-100%
B= 1-5%	D= 25-50%	F= 75-95%	

Table 2. Plant Species Coverage in No-Mow Zone 2.

No-Mow Zone 2 contained 9 species, the dominant species were Canadian Wild Rye (40% frequency, 5% coverage), Common Dandelion (35% frequency, 7% coverage), Common Morning Glory (25% frequency, 2% coverage), Kentucky Bluegrass (85% frequency, 26% coverage), Switchgrass (60% frequency, 18% coverage).

Site: N-M-2
Date: 10/10/13

GPS: 40°5'48"N 88°12'34"W
Stake 1: 40°05'47.42"N 88°12'36.76"W
Stake 2: 40°05'45.10"N 88°12'39.86"W

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Frequency (%)	Percentage(%)
Bald Cypress																					0	0
Canadian Wild Rye		B	C		D				C		B	B					B	C			40	5
Common Dandelion			B	C			D			C		C					D		C		35	7
Common Hackberry																					0	0
Common Milk Weed																					0	0
Common Morning Glory	C			B		B	C		B												25	2
Curly Dock																					0	0
Eastern Red Cedar																					0	0
Field Nut Sedge																					0	0
Field Thistle						B															5	1
Frost Aster																					0	0
Garlic Mustard																					0	0
Japanese Honeysuckle																					0	0
Kentucky Blue Grass	F	E	B	E	D	D	D	C		C	C	B	B		D	D		D	C	C	85	26
Lamb's Quarters			C																		5	1
Northern Red Oak	F																				5	4
Norway Spruce																					0	0
Old field Goldenrod																					0	0
Pennsylvania Smartweed																					0	0
Pokeweed																					0	0
Prairie Blazing Star																					0	0
Switchgrass	C		D	C	D				E	D	D	C	C		D	C		D			60	18
Western Ragweed																					0	0
Yellow Wood Sorrel							C		B												10	1

Percent Cover Classes:

A= <1%	C= 5-25%	E= 50-75%	G= 95-100%
B= 1-5%	D= 25-50%	F= 75-95%	

Table 3. Plant Species Coverage in No-Mow Zone 3.

No-Mow Zone 3 contained 11 species, the dominant species were Canadian Wild Rye (20% frequency, 6% coverage), Common Dandelion (30% frequency, 4% coverage), Common Morning Glory (85% frequency, 27% coverage), Kentucky Bluegrass (60% frequency, 22% coverage), Lamb's Quarters (20% frequency, 3% coverage), Prairie Blazing Star (15% frequency, 2% coverage), Switchgrass (20% frequency,1% coverage) and Yellow Wood Sorrel (30% frequency, 3% coverage).

Site: N-M-3
Date: 10/10/13

GPS: 40°5'46"N 88°12'34"W
Stake 1: 40°05'49.62"N 88°12'44.12"W
Stake 2: 40°05'46.38"N 88°12'43.75"W

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Frequency (%)	Percentage (%)
Bald Cypress																					0	0
Canadian Wild Rye											C	C	E						C		20	6
Common Dandelion		C					D					C				B			C	A	30	4
Common Hackberry																					0	0
Common Milk Weed																					0	0
Common Morning Glory	E	B	C	D	D	C	C	C	D	C	C	E	D	B		E		E	D		85	27
Curly Dock																					0	0
Eastern Red Cedar																					0	0
Field Nut Sedge																					0	0
Field Thistle																					0	0
Frost Aster																					0	0
Garlic Mustard																					0	0
Japanese Honeysuckle																D		E			10	5
Kentucky Blue Grass	D			C	C	C					D	D	D	E	E	C			C	F	60	22
Lamb's Quarters		D			B		B					B									20	3
Northern Red Oak						E															5	3
Norway Spruce																					0	0
Old field Goldenrod											C	D									10	3
Pennsylvania Smartweed																					0	0
Pokeweed																					0	0
Prairie Blazing Star															C		C			C	15	2
Switchgrass	B								B		C									B	20	1
Western Ragweed																					0	0
Yellow Wood Sorrel	C	C	C		B	C	B														30	3

Percent Cover Classes:

A= <1%	C= 5-25%	E= 50-75%	G= 95-100%
B= 1-5%	D= 25-50%	F= 75-95%	

Table 4. Plant Species Coverage in No-Mow Zone 4.

No-Mow Zone 4 contained 16 species, the dominant species were Canadian Wild Rye (10% frequency, 9% coverage), Common Dandelion (10% frequency, 2% coverage), Common Morning Glory (60% frequency, 13% coverage), Field Thistle (80% frequency, 13% coverage), Kentucky Bluegrass (80% frequency, 67% coverage), Pokeweed (10% frequency, 4% coverage).

Site: N-M-4
Date: 10/10/13

GPS: 40°5'39"N 88°13'16"W
Stake 1: 40°5'37.90"N 88°13'10.15"W
Stake 2: 40°5'34.35"N 88°13'10.05"W

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Frequency (%)	Percentage (%)
Bald Cypress								C													5	1
Canadian Wild Rye							F	F													10	9
Common Dandelion			C	C																	10	2
Common Hackberry																					0	0
Common Milk Weed																					0	0
Common Morning Glory	F	E	D	C	B	C		C			B			B		B	B		B		60	13
Curly Dock																					0	0
Eastern Red Cedar						E															5	3
Field Nut Sedge				B																	5	1
Field Thistle	B		B	C			C	C	C	B	C	E		A	B	B	D	C	C	D	80	13
Frost Aster								E													5	3
Garlic Mustard			B		B																10	1
Japanese Honeysuckle	C	D																			10	3
Kentucky Blue Grass	F	E	F	F	C	C			E	F	F	F	F	F	F	F	F	F	F	F	80	67
Lamb's Quarters																	E				5	3
Northern Red Oak						C															5	1
Norway Spruce					E																5	3
Old field Goldenrod																					0	0
Pennsylvania Smartweed																					0	0
Pokeweed			C		B	B		C	B	A	C			B	B	C					10	4
Prairie Blazing Star							C														5	1
Switchgrass																					0	0
Western Ragweed																					0	0
Yellow Wood Sorrel																					0	0

Percent Cover Classes:

A= <1%	C= 5-25%	E= 50-75%	G= 95-100%
B= 1-5%	D= 25-50%	F= 75-95%	

Table 5. Plant Species Coverage in No-Mow Zone 5.

No-Mow Zone 5 contained 10 species, the dominant species were Common Morning Glory (75% frequency, 14% coverage), Field Thistle (35% frequency, 7% coverage), Garlic Mustard (50% frequency, 13% coverage), Kentucky Bluegrass (100% frequency, 40% coverage), Pokeweed (70% frequency, 9% coverage) and Yellow Wood Sorrel (20% frequency, 6% coverage).

Site: N-M-5
Date: 10/10/13
GPS: 40°5'39"N 88°13'9"W
Stake 1: 40°5'28.07"N 88°13'13.71"W
Stake 2: 40°05'28.18"N 88°13'09.55"W

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Frequency (%)	Percentage (%)
Bald Cypress																					0	0
Canadian Wild Rye																					0	0
Common Dandelion					C																5	1
Common Hackberry																					0	0
Common Milk Weed																					0	0
Common Morning Glory	E		D	C	C	C	C		C	D	B			B	B	B	C	C		C	75	14
Curly Dock											F										5	4
Eastern Red Cedar																					0	0
Field Nut Sedge																					0	0
Field Thistle	C						E				B		C		B	B			D		35	7
Frost Aster																					0	0
Garlic Mustard	A	E	C		B			C			D				E		C		D	B	50	13
Japanese Honeysuckle																					0	0
Kentucky Blue Grass	F	F	C	E	D	E	E	B	D	B	D	D	B	B	E	E	E	D	C	C	100	40
Lamb's Quarters																					0	0
Northern Red Oak																					0	0
Norway Spruce																					0	0
Old field Goldenrod											C										5	1
Pennsylvania Smartweed								B													5	1
Pokeweed	C	C	D	B	B	B			B	B	C		B		D		C	C	B		70	9
Prairie Blazing Star																					0	0
Switchgrass																					0	0
Western Ragweed																					0	0
Yellow Wood Sorrel						C	C		E								C				20	6

Percent Cover Classes:

A= <1%	C= 5-25%	E= 50-75%	G= 95-100%
B= 1-5%	D= 25-50%	F= 75-95%	

Table 6. Plant Species Coverage in Meadowbrook Park 1.

There were 30 species on the four Meadowbrook Park transects. Meadowbrook Park 1 contained 17 species, the dominant species were Big Bluestem (75% frequency, 30% coverage), Common Goldenrod (85% frequency, 30% coverage), Indian Grass (100% frequency, 36% coverage), Wild Bergamot (20% frequency, 4% coverage), Penstemon (35% frequency, 4% coverage) and Yellow Coneflower (35% frequency, 2% coverage).

Site: Meadowbrook 1
Date: 9/15/06
GPS: 468E, 209N
Stake 1: 397384, 443715 Cetrex 116
Stake 2: 397468,4437209 Cetrex 117

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Frequency (%)	Coverage (%)
Big Bluestem	C	D	C	D	D	D	C	F		E	E	E	D	C	E						75	30
Black-Eyed Susan			A														A				10	1
Bush Clover	A																				5	1
Common Goldenrod	D		A			C	C	C	F	D	E	D	D	5	D	C	C	E	E		85	30
Compass Plant	B	A																			10	1
Cream Gentian																					0	0
Culver's Root																					0	0
Field Goldenrod																					0	0
Golden Alexander																					0	0
Indian Grass	C	C	D	D	D	D	C	A	C	E	D	E	C	C	D	E	E	E	D		100	36
Kentucky Bluegrass																					0	0
Little Bluestem									C												5	1
Mountain Mint			A	A	A																15	1
Pale Penstemon	A						C						A	C		A	D	A			35	4
Pasture Thistle																					0	0
Prairie Dock				C							A										10	1
Prairie Sunflower													A								5	1
Purple Coneflower				A						A		A					A				20	1
Rattlesnake Master	B																				5	1
Rosinweed																					0	0
Stiff Goldenrod				B																	5	1
Sweet Clover																					0	0
Switchgrass																					0	0
Tall Coreopsis																					0	0
Thimble Weed																					0	0
Tick Trefoil							A							C	B						15	1
White Indigo																					0	0
Wild Bergamot	D	C		C					A												20	4
Wild Strawberry																					0	0
Yellow Coneflower		A		A	C	B	B					B				A					35	2

Percent Cover Classes:

A= <1%	C= 5-25%	E= 50-75%	G= 95-100%
B= 1-5%	D= 25-50%	F= 75-95%	

Table 7. Plant Species Coverage in Meadowbrook Park 2.

Meadowbrook Park 2 contained 17 species, the dominant species were Big Bluestem (50% frequency, 8% coverage), Bush Clover (55% frequency, 10% coverage), Common Goldenrod (50% frequency, 4% coverage), Compass Plant (20% frequency, 6% coverage), Cream Gentian (80% frequency, 24% coverage), Indian Grass (80% frequency, 13% coverage), Purple Coneflower (85% frequency, 13% coverage), Rattlesnake Master (45% frequency, 8% coverage), Tall Coreopsis (60% frequency, 9% coverage) and White Indigo (55% frequency, 13% coverage).

Site: Meadowbrook 2
Date: 9/15/06

GPS: 397143E, 4437180N
stake1: 7143E, 7178N — Cetrex 110
stake2: 7149E, 7080N — Cetrex 111

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Frequency (%)	Coverage (%)
Big Blue Stem	B	C	B	C	E		B	D		B						A	C				50	8
Black-Eyed Susan		B	C		C		B	C		C	C	D	C		C	C		B			60	9
Bush Clover	A	B	C	C	C	D	D	D		C			B	B							55	10
Common Goldenrod	A	A			A	A	A				D			C	B	B				C	50	4
Compass Plant	B	B				E	D														20	6
Cream Gentian	A	D	D	E	B	C	D	C	C	C	C	C	B	C	E	F		B		D	80	24
Culver's Root																					0	0
Field Goldenrod																					0	0
Golden Alexander	C	A				A								C		B	B				30	2
Indian Grass	C	B	B	B		D	C	C			A	C	C	C	C		C	E	C	C	80	13
Kentucky Bluegrass																					0	0
Little Bluestem																					0	0
Mountain Mint	A																				5	0
Pale Penstemon																					0	0
Pasture Thistle																					0	0
Prairie Dock			C					C				B									15	2
Prairie Sunflower																			C		5	1
Purple Coneflower	A	A	B		C	D	B	B	C	C	C	C	C	C		C	B	E		C	85	13
Rattlesnake Master	A			A				B				D		C	B	C		C		E	45	8
Rosinweed																					0	0
Stiff Goldenrod																					0	0
Sweet Clover																					0	0
Switchgrass																					0	0
Tall Coreopsis																					0	0
Thimble Weed																					0	0
Tick Trefoil			B		B						B				A		B	B	B		35	1
White Indigo	C		C	B	D	C					D		B	D	C		E		C		55	13
Wild Bergamot	B								C		B	C					B				25	2
Wild Strawberry		B	C	B	B					B	A										30	2
Yellow Coneflower		C	B			A											C				20	2

Percent Cover Classes:

A= <1% C= 5-25% E= 50-75% G= 95-100%

B= 1-5% D= 25-50% F= 75-95%

Table 8. Plant Species Coverage in Meadowbrook Park 3.

Meadowbrook Park 3 contained 15 species, the dominant species were Big Bluestem (95% frequency, 23% coverage), Common Goldenrod (95% frequency, 30% coverage), Indian Grass (65% frequency, 10% coverage), Kentucky Bluegrass (55% frequency, 23% coverage) and Wild Bergamot (40% frequency, 6% coverage).

Site: Meadowbrook 3
Date: 9/15/06
GPS: 372E, 228N
stake 1: 7311E, 7250N — C etrex 184
stake 2: 7220E, 7220N — C etrex 156

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Frequency (%)	Coverage (%)
Big Blue Stem	C	C	E	E	C	D	B	C	D	C	D	B	C		C	A	C	C	E	B	95	23
Black-Eyed Susan					A								A								10	1
Bush Clover															A						5	1
Common Goldenrod	D	C	C	B	E	D	B	C	C	B	B	E	C	E		F	D	C	D	E	95	30
Compass Plant							C				A							B			15	1
Cream Gentian																				A	5	1
Culver's Root																	A				5	1
Field Goldenrod															C						5	1
Golden Alexander																	A				5	1
Indian Grass	C	C	B	B			D	B	D	C	D		B	A	B		C				65	10
Kentucky Bluegrass	B	B			B			B	A	B	A			C		B	C		A		55	3
Little Bluestem																					0	0
Mountain Mint																					0	0
Pale Penstemon																					0	0
Pasture Thistle																					0	0
Prairie Dock															C						5	1
Prairie Sunflower										C											5	1
Purple Coneflower																A	A				10	1
Rattlesnake Master																					0	0
Rosinweed																					0	0
Stiff Goldenrod																					0	0
Sweet Clover																					0	0
Switchgrass																					0	0
Tall Coreopsis																					0	0
Thimble Weed																					0	0
Tick Trefoil																					0	0
White Indigo																					0	0
Wild Bergamot						C						B		A	A	D	C	B	D		40	6
Wild Strawberry																					0	0
Yellow Coneflower																					0	0

Percent Cover Classes:

A= <1%	C= 5-25%	E= 50-75%	G= 95-100%
B= 1-5%	D= 25-50%	F= 75-95%	

Table 9. Plant Species Coverage in Meadowbrook Park 4.

Meadowbrook Park 4 contained 18 species, the dominant species were Big Bluestem (70% frequency, 17% coverage), Common Goldenrod (80% frequency, 23% coverage), Cream Gentian (55% frequency, 10% coverage), Indian Grass (85% frequency, 19% coverage), Purple Coneflower (85% frequency, 13% coverage), Field Goldenrod (25% frequency, 4% coverage) and White Indigo (55% frequency, 13% coverage).

Site: Meadowbrook 4
Date: 9/15/06
GPS: 7130E, 7170N
stake 1: 7130E, 7175N — cetrex 119
stake 2: 7051E, 7115N — cetrex 120

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Frequency (%)	Coverage (%)
Big Blue Stem		C	E		D		B	C		B		A	C	E	D	C	E		B	C	70	17
Black-Eyed Susan																					0	0
Bush Clover				B													C	A			15	1
Common Goldenrod	E	C	C	C			B	C	F	C		C	D	D	C	E		B	C	D	80	23
Compass Plant			A	A					D												15	2
Cream Gentian				C		D	C	C	C	C		C	C	D	B		C				55	10
Culver's Root																					0	0
Field Goldenrod				C						D	C						B		B		25	4
Golden Alexander						A					C	B		B				C			25	2
Indian Grass	B		E	B	C		C	A	C	C	D	E	B		E	A	C	D	C	C	85	19
Kentucky Bluegrass																					0	0
Little Bluestem																					0	0
Mountain Mint																					0	0
Pale Penstemon																				A	5	1
Pasture Thistle	B																				5	1
Prairie Dock								C												A	10	1
Prairie Sunflower																					0	0
Purple Coneflower																					0	0
Rattlesnake Master					B	E	C	A	C	A	C			A	B	B		B			55	6
Rosinweed																					0	0
Stiff Goldenrod																					0	0
Sweet Clover																					0	0
Switchgrass																					0	0
Tall Coreopsis																					0	0
Thimble Weed												B					B				10	1
Tick Trefoil					B						C										10	1
White Indigo					B	D	E		B	B	E		C			A	C	A	E	A	60	14
Wild Bergamot	B									A		A	C	A	C			A			35	2
Wild Strawberry						A															5	1
Yellow Coneflower											B				C						10	1

Percent Cover Classes:

A= <1%	C= 5-25%	E= 50-75%	G= 95-100%
B= 1-5%	D= 25-50%	F= 75-95%	

3.2.1 No-Mow Zone Transects

There were 24 species found collectively on the five No-Mow Zone transects, including 17 flowering species and 7 non-flowering species (Table 1-5). Each No-Mow Zone contained 9-16 species. No-Mow Zone 1 contained 9 species, the dominant species were Canadian Wild Rye (60% frequency, 10% coverage), Common Dandelion (65% frequency, 11% coverage), Kentucky Bluegrass (95% frequency, 32% coverage), Switchgrass (75% frequency, 22% coverage).

No-Mow Zone 2 contained 9 species, the dominant species are Canadian Wild Rye (40% frequency, 5% coverage), Common Dandelion (35% frequency, 7% coverage), Common Morning Glory (25% frequency, 2% coverage), Kentucky Bluegrass (85% frequency, 26% coverage), Switchgrass (60% frequency, 18% coverage).

No-Mow Zone 3 contained 11 species, the dominant species were Canadian Wild Rye (20% frequency, 6% coverage), Common Dandelion (30% frequency, 4% coverage), Common Morning Glory (85% frequency, 27% coverage), Kentucky Bluegrass (60% frequency, 22% coverage), Lamb's Quarters (20% frequency, 3% coverage), Prairie Blazing Star (15% frequency, 2% coverage), Switchgrass (20% frequency,1% coverage) and Yellow Wood Sorrel (30% frequency, 3% coverage).

No-Mow Zone 4 contained 16 species, the dominant species were Canadian Wild Rye (10% frequency, 9% coverage), Common Dandelion (10% frequency, 2% coverage), Common Morning Glory (60% frequency, 13% coverage), Field Thistle (80% frequency, 13% coverage), Kentucky Bluegrass (80% frequency, 67% coverage), Pokeweed (10% frequency, 4% coverage).

No-Mow Zone 5 contained 10 species, the dominant species were Common Morning Glory (75% frequency, 14% coverage), Field Thistle (35% frequency, 7% coverage), Garlic Mustard (50% frequency, 13% coverage), Kentucky Bluegrass (100% frequency, 40% coverage),

Pokeweed (70% frequency, 9% coverage) and Yellow Wood Sorrel (20% frequency, 6% coverage).

The dominant species of the five No-Mow Zones were Canadian Wild Rye (frequency 26%, coverage 6%), Common Dandelion (frequency 28%, coverage 5%), Common Morning Glory (frequency 13%, coverage 12%), Kentucky Bluegrass (frequency 84%, coverage 38%), Switch Grass (frequency 31%, coverage 8%). These species accounted for nearly eighty percent of plant coverage.

Each of the No-Mow Zone, transects had 3-7 flowering species. The dominant flowering species of the five No-Mow Zones were Common Dandelion (frequency 28%, coverage 5%), Common Morning Glory (frequency 13%, coverage 12%), Yellow Wood Sorrel (12% frequency, 2% coverage) and Pokeweed (16% frequency, 2% coverage). Other flowering species accounted for less than 5% frequency and/or 1% coverage.

3.2.2 Prairie Transects

There were 30 species found collectively on the four prairie zone transects, including 25 flowering species and 5 non-flowering species (Tables 6-9). Each transect contained 15-18 species. Meadowbrook Park 1 contained 17 species, the dominant species were Big Bluestem (75% frequency, 30% coverage), Common Goldenrod (85% frequency, 30% coverage), Indian Grass (100% frequency, 36% coverage), Wild Bergamot (20% frequency, 4% coverage), Penstemon (35% frequency, 4% coverage) and Yellow Coneflower (35% frequency, 2% coverage).

Meadowbrook Park 2 contained 17 species, the dominant species were Big Bluestem (50% frequency, 8% coverage), Bush Clover (55% frequency, 10% coverage), Common Goldenrod (50% frequency, 4% coverage), Compass Plant (20% frequency, 6% coverage), Cream Gentian

(80% frequency, 24% coverage), Indian Grass (80% frequency, 13% coverage), Purple Coneflower (85% frequency, 13% coverage), Rattlesnake Master (45% frequency, 8% coverage), Tall Coreopsis (60% frequency, 9% coverage) and White Indigo (55% frequency, 13% coverage).

Meadowbrook Park 3 contained 15 species, the dominant species Big Bluestem (95% frequency, 23% coverage), Common Goldenrod (95% frequency, 30% coverage), Indian Grass (65% frequency, 10% coverage), Kentucky Bluegrass (55% frequency, 23% coverage) and Wild Bergamot (40% frequency, 6% coverage).

Meadowbrook Park 4 contained 18 species, the dominant species Big Bluestem (70% frequency, 17% coverage), Common Goldenrod (80% frequency, 23% coverage), Cream Gentian (55% frequency, 10% coverage), Indian Grass (85% frequency, 19% coverage), Purple Coneflower (85% frequency, 13% coverage), Field Goldenrod (25% frequency, 4% coverage) and White Indigo (55% frequency, 13% coverage).

The dominant flowering species of the prairie zone included Common Goldenrod (75% frequency, 22% coverage), Cream Gentian (35% frequency, 9% coverage), Wild Bergamot (30% frequency, 4% coverage), Purple Coneflower (29% frequency, 4% coverage), White Indigo (29% frequency, 7% coverage) and Rattlesnake Master (26% frequency, 4% coverage). The non-flowering species, were Big Bluestem (72% frequency, 19% coverage) and Indian Grass (85% frequency, 19% coverage). These above species accounted for nearly ninety percent of the plant coverage. Other flowering species exhibited less than 5% frequency and/or 1% coverage.

3.3 Species Characteristics

Tables 10 and 11 describe the characteristics of species in no-mow and prairie zones, including species name, scientific name, species frequency, species coverage, height, flower color, blooming time and environmental requirements (soil, water, sun).

Table 10. Characteristics of Species in No-Mow Zones.

This table describes the characteristics of species in No-Mow Zones, including species name, scientific name, species frequency, species coverage, height, flower color, blooming time and environmental requirements (soil, water, sun).

common name	scientific name	frequency(%)	coverage(%)	height	sun	water	flower color	bloom time
Bald Cypress	*Taxodium distichum*	1	1	80-120'	full	wet to moist	N/A	N/A
Canadian Wild Rye	*Elymus canadensis glaucifolius*	26	6	3-5'	full or partial	moist to dry	N/A	N/A
Common Dandelion	*Taraxacum officinale*	29	5	12-18"	full	mesic	yellow	early spring to late fall
Common Hackberry	*Celtis occidentalis*	0	0	40-80'	full or partial	moist to mesic	yellowish green	mid spring to late spring
Common Milk Weed	*Asclepias syriaca*	0	0	2-6'	full	mesic	light pink	1-1½ months from early to mid-summer
Common Morning Glory	*Ipomoea purpurea*	50	12	1-2'	full or partial	moist to mesic	purple, blue, pink	mid-summer to fall and lasts 2-3 months
Curly Dock	*Rumex crispus*	1	1	1-3'	full sun	moist to dry	yellowish green	summer and lasts about a month.
Eastern Red Cedar	*Juniperus virginiana*	1	1	30-80'	full	mesic to dry	N/A	N/A
Field Nut Sedge	*Cyperus esculentus*	1	1	0.5-2'	full or partial	wet to mesic	white	mid-summer to early fall
Field Thistle	*Cirsium discolor*	24	5	2-7'	full	moist to wet	pink to pinkish purple	mid-summer to early fall
Frost Aster	*Aster pilosus*	2	1	3.5'	full	mesic to dry	white	fall for about 1½ months.
Garlic Mustard	*Alliaria petiolata*	12	3	1-3'	partial shade	moist to mesic	white	late spring or early summer
Japanese Honeysuckle	*Lonicera japonica*	4	2	60'	partial	moist to mesic	white , golden	two months during summer
Kentucky Blue Grass	*Poa pratensis*	84	38	1.5-2.5'	full or partial	mesic	N/A	N/A
Lamb's Quarters	*Chenopodium album*	6	2	1-6'	full	mesic	white	mid-summer through the fall
Northern Red Oak	*Quercus rubra*	4	3	60-100'	full or partial	mesic to mesic	yellowish green	mid spring to late spring
Norway Spruce	*Picea abies*	1	1	50-120'	full or partial	moist	N/A	N/A
Old field Goldenrod	*Solidago nemoralis*	3	1	0.5-2.5'	full	dry to mesic dry	yellow	fall, one month
Pennsylvania Smartweed	*Persicaria pensylvanica laevigata*	1	1	1-4'	full or partial	moist	white, pink	summer to early autumn
Pokeweed	*Phytolacca americana*	17	3	up to 8'	partial	moist	white or pink	mid summer to fall
Prairie Blazing Star	*Liatris pycnostachya*	4	1	4'	full or partial	moist to mesic	pink to purplish pink	during late summer
Switchgrass	*Panicum virgatum*	31	9	3-6'	full or partial	moist to mesic	N/A	N/A
Western Ragweed	*Ambrosia psilostachya*	3	1	1-2'	full	dry	green,yellow	mid summer to fall
Yellow Wood Sorrel	*Oxalis fontana*	12	2	5-12"	light to full	moist to mesic	yellow	late spring to the mid-autumn

Table 11. Characteristics of Species in Meadowbrook Park.

This table describes the characteristics of species in Meadowbrook Park, including species name, scientific name, species frequency, species coverage, height, flower color, blooming time and environmental requirements (soil, water, sun).

common name	scientific name	frequency(%)	coverage(%)	height	sun	water	flower color	bloom time
Big Bluestem	*Andropogon gerardii*	73	20	3-8'	full	moist to slightly dry	N/A	N/A
Black-Eyed Susan	*Rudbeckia hirta*	20	3	1-2.5'	full	mesic to dry	yellow	early to mid summer
Bush Clover	*Lespedeza capitata*	20	4	2-5'	full	moist to slightly dry	white	late summer to early fall
Common Goldenrod	*Solidago canadensis*	78	22	2-6'	full	moist to slightly dry	yellow	late summer to fall
Compass Plant	*Silphium laciniatum*	15	3	6-12'	full	moist to slight dry	yellow	mid summer,1.5 month
Cream Gentian	*Gentiana alba*	35	9	1-2'	full or partial	moist to average	white	late summer, 1-1.5 months
Culver's Root	*Veronicastrum virginicum*	2	1	5'	full or partial	moist to average	white	early to mid summer, 1 month
Field Goldenrod	*Solidago nemoralis*	8	2	0.5-2.5'	full	mesic to dry	yellow	fall
Golden Alexanders	*Zizia aurea*	15	2	2.5'	full or partial	moist loamy	yellow	late spring to late summer, 1 month
Indian Grass	*Sorghastrum nutans*	83	20	3-7'	full or partial	moist to slight dry	N/A	N/A
Kentucky Bluegrass	*Poa pratensis*	14	1	1.5-2.5'	full or partial	mesic	N/A	N/A
Little Bluestem	*Schizachyrium scoparium*	2	1	2-3'	full	mesic to dry	N/A	N/A
Mountain Mint	*Pycnanthemum virginianum*	5	1	up to 3‘	full	dry to moist	white	during summer
Pale Penstemon	*Penstemon pallidus*	10	2	1-2.5'	full or partial	moist to dry	light purple	mid spring to early summer,3 weeks
Pasture Thistle	*Cirsium discolor*	2	1	2-8'	full	dry to moist	light pink	late summer to fall,1 month
Prairie Dock	*Silphium terebinthinaceum*	10	2	3-10'	full	moist to slight dry	yellow	late summer to early fall, 1 month
Prairie Sunflower	*Helianthus pauciflorus*	4	1	2-4'	full	dry to moist	yellow	late summer to fall,1-2 month
Purple Coneflower	*Echinacea purpurea*	29	4	3.5'	full or partial	moist to mesic	purple	mid summer or early fall, 1 month
Rattlesnake Master	*Eryngium yuccifolium*	26	4	2-5'	full	moist to slight dry	light green	mid to late summer
Rosinweed	*Silphium integrifolium*	0	0	3-5'	full	mesic to dry	yellow	mid summer to fall
Stiff Goldenrod	*Solldago rigida*	2	1	2-5'	full	moist to slight dry	yellow	late summer to fall,1 month
Sweet Clover	*Melilotus officinalis*	0	0	2-7'	full	moist to slight dry	yellow	late spring to early fall
Switchgrass	*Panicum virgatum*	0	0	3-6'	full or partial	moist to mesic	N/A	N/A
Tall Coreopsis	*Coreopsis tripteris*	0	0	4-8'	full or partial	moist to mesic	yellow	1-2 months
Thimble Weed	*Anemone cylindrica*	3	1	1-2'	full	moist to mesic	purple	early to mid summer, 1 month
Tick Trefoil	*Desmodium illinoense*	15	1	2.5-4'	mesic	moist to slight dry	purple	mid summer
White Indigo	*Baptisia alba macrophylla*	29	7	3-6'	full	moist to slight dry	white	late spring to mid-summer
Wild Bergamot	*Monarda fistulosa*	30	4	2.5-4'	full or partial	mesic to dry	purple	mid summer
Wild Strawberry	*Fragaria virginiana*	9	1	2'	full or partial	moist to slight dry	white	late spring to early summer 1-2 months
Yellow Coneflower	*Ratibida pinnata*	17	2	4'	full	mesic	yellow	early to late summer, 1-2 months

3.4 Ecological Indices - Results

3.4.1 Species Similarity

The Species Similarity Index was used to determine the similarity of plant species among transects, within each plant community (e.g. No-Mow Zones or Meadowbrook Park) (Tables 12 and 13).To determine the index, the number of species occurring in each transect, and the in-common number of species (occurring in both transects) are determined. The Species Similarity Index equals two times the "in-common number" of species divided by the sum of the species from both transects (Tables 13 and 14).

Similarity indices ranged from 42.1 to 80.0 in the No-Mow Zones and from 60.6 to 80.0 in Meadowbrook Park. The average similarity is significantly greater ($p < 0.013$) in Meadowbrook Park (0.69) than in the No-Mow Zones (0.56) (Tables 14 and 15).

Table 12. Species Occurrences in No-Mow Zones Used to Determine the Similarity Indices among the Transects of Meadowbrook Park.

N-M 1	N-M2		N-M 1	N-M 3		N-M 1	N-M 4		N-M 1	N-M 5		N-M2	N-M 3		N-M2	N-M 4		N-M2	N-M 5		N-M 3	N-M 4		N-M 3	N-M 5		N-M 4	N-M 5	
occur	occur	in both	occur	occur	in both	occur	occur	in both	occur	occur	in both	occur	occur	in both	occur	occur	in both	occur	occur	in both	occur	occur	in both	occur	occur	in both	occur	occur	in both
0	0		0	0		0	1		0	0		0	0		0	1		0	0		0	1		0	0		1	0	
1	1	1	1	1	1	1	1	1	1	0		1	1	1	1	1	1	1	0		1	1	1	1	0		1	0	
1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0	0		0	0		0	0		0	0		0	0		0	0		0	0		0	0		0	0		0	0	
0	0		0	0		0	0		0	0		0	0		0	0		0	0		0	0		0	0		0	0	
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0	0		0	0		0	0		0	1		0	0		0	0		0	1		0	0		0	1		0	1	
0	0		0	0		0	1		0	0		0	0		0	1		0	0		0	1		0	0		1	0	
0	0		0	0		0	1		0	0		0	0		0	1		0	0		0	1		0	0		1	0	
0	1		0	0		0	1		0	1		1	0		1	1	1	1	1	1	0	1		0	1		1	1	1
1	0		1	0		1	1	1	1	0		0	0		0	1		0	0		0	1		0	0		1	0	
0	0		0	0		0	1		0	1		0	0		0	1		0	1		0	1		0	1		1	1	1
0	0		0	1		0	1		0	0		0	1		0	1		0	0		1	1	1	1	0		1	0	
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0	1		0	1		0	1		0	0		1	1	1	1	1	1	1	0		1	1	1	1	0		1	0	
1	1	1	1	1	1	1	1	1	1	0		1	1	1	1	1	1	1	0		1	1	1	1	0		1	0	
0	0		0	0		0	1		0	0		0	0		0	1		0	0		0	1		0	0		1	0	
0	0		0	1		0	0		0	1		0	1		0	0		0	1		1	0		1	1	1	0	1	
0	0		0	0		0	0		0	1		0	0		0	0		0	1		0	1		0	1		0	1	
1	0		1	0		1	1	1	1	1	1	0	0		0	1		0	1		0	1		0	1		1	1	1
0	0		0	1		0	1		0	0		0	1		0	1		0	0		1	1	1	1	0		1	0	
1	1	1	1	1	1	1	0		1	0		1	1	1	1	0		1	0		1	0		1	0		0	0	
1	0		1	0		1	0		1	0		0	0		0	0		0	0		0	0		0	0		0	0	
0	1		0	1		0	0		0	1		1	1	1	1	0		1	1	1	1	0		1	1	1	0	1	
9	9	5	9	11	6	9	16	7	9	10	4	9	11	8	9	16	7	9	10	5	11	16	8	11	10	5	16	10	6
similarity index=			similarity index=			similarity index=			similarity index=			similarity index=			similarity index=			similarity index=			similarity index=			similarity index=					
55.6%			60.0%			56.0%			42.1%			80.0%			56.0%			52.6%			59.3%			47.6%			46.2%		

Table 13. Species occurrences in Meadowbrook Park used to determine the similarity indices among transects of Meadowbrook Park.

M1	M2		M1	M3		M1	M4		M2	M3		M2	M4		M3	M4
Occurance	Occurance	In Both	Occurance	Occurance	In Both	Occurance	Occurance	In Both	Occurance	Occurance	In Both	Occurance	Occurance		Occurance	Occurance
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	0		1	1	1	1	0		1	0
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0	1		0	1		0	1		1	1	1	1	1	1	1	1
0	0		0	1		0	0		0	1		0	0		1	0
0	0		0	1		0	1		0	1		0	1		1	1
0	1		0	1		0	1		1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0	0		0	1		0	0		0	1		0	0		1	0
1	0		1	0		1	0		0	0		0	0		0	0
1	1	1	1	0		1	0		1	0		1	0		0	0
1	0		1	0		1	1	1	0	0		0	1		0	1
0	0		0	0		0	1		0	0		0	1		0	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	0		1	1	1	1	0		1	0
1	1	1	1	1	1	1	0		1	1	1	1	0		1	0
1	1	1	1	0		1	1	1	1	0		1	1	1	0	1
0	0		0	0		0	0		0	0		0	0		0	0
1	0		1	0		1	0		0	0		0	0		0	0
0	0		0	0		0	0		0	0		0	0		0	0
0	0		0	0		0	0		0	0		0	0		0	0
0	0		0	0		0	0		0	0		0	0		0	0
0	0		0	0		0	1		0	0		0	1		0	1
1	1	1	1	0		1	1	1	1	0		1	1	1	0	1
0	1		0	0		0	1		1	0		1	1	1	0	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0	1		0	0		0	1		1	0		1	1	1	0	1
1	1	1	1	0		1	1	1	1	0		1	1	1	0	1
17	18	14	17	15	10	17	18	11	18	15	12	18	18	14	15	18
index of similarity=		80.0%	index of similarity=		62.5%	index of similarity=		62.9%	index of similarity=		72.7%	index of similarity=		77.8%	index of similarity=	

Table 14. Similarity Index of Each Two Transects of Meadowbrook Park and No-Mow Zones.

Similarity Index			
Meadowbrook		No-Mow	
1-2	80.0%	1-2	55.6%
1-3	62.5%	1-3	60.0%
1-4	62.9%	1-4	56.0%
2-3	72.7%	1-5	42.1%
2-4	77.8%	2-3	80.0%
3-4	60.6%	2-4	56.0%
		2-5	52.6%
		2-4	59.3%
		2-5	47.6%
		4-5	46.2%

Table 15. t-Test: Two-Sample Assuming Unequal Variances Comparing Species Similarity.

Results indicate species have a higher similarity in Meadowbrook Park than in No-Mow Zones.

	meadow	*no mow*
Mean	0.6941	0.555324551
Variance	0.00723262	0.010802571
Observations	6	10
Hypothesized Mean Difference	0	
Df	12	
t Stat	2.9027098	
P(T<=t) one-tail	**0.007**	
t Critical one-tail	1.782287556	
P(T<=t) two-tail	**0.013**	
t Critical two-tail	2.17881283	

3.4.2 Species Richness

Table 16. Species Richness of Each Transect in No-Mow Zones and Meadowbrook Park.

	transect	species richness
No-Mow Zones	1	9
	2	9
	3	11
	4	16
	5	10

	transect	species richness
Meadowbrook Park	1	17
	2	18
	3	15
	4	18

.

Species richness values for each transect in the No-Mow Zones raged from 9 to 16, while those in Meadowbrook Park ranged from 15 to 18 (Table 16). Average species richness of the Meadowbrook Park transects (17) was significantly greater than that of the No-Mow Zones (11) ($p < 0.001$, Table 17).

Table 17. t-Test: Two-Sample Assuming Unequal Variances Comparing Species Richness between No-Mow Zones and Meadowbrook Park.

	Meadowbrook	*No-Mow Zones*
Mean	17	11
Variance	2	8.5
Observations	4	5
Hypothesized Mean Difference	0	
Df	6	
t Stat	4.045199175	
P(T<=t) one-tail	**0.003**	
t Critical one-tail	1.943180281	
P(T<=t) two-tail	**0.007**	
t Critical two-tail	2.446911851	

3.4.3 Species Diversity

To compare the degree of dominance, the Simpson index (1-D) is often used. It is calculated by squaring the ratios for each kind and summing them, thus D= Σ (ni/N)2 (Odum, 1993). Here ni is the coverage of each species of each transect, N is the total coverage of each transect. Tables 17 and 18 show the Simpson index (1-D) of each transect in No-Mow Zones and Meadowbrook Park, respectively.

Table 18. Simpson Index of Species (1-D) in No-Mow Zones.

The higher the D value, the higher the diversity. Otherwise, using 1-D, the higher the number, the lower the diversity.

	N-M 1	N-M 2	N-M3	N-M4	N-M 5
Species	(ni/N)2	(ni/N)2	(ni/N)2	(ni/N)2	(ni/N)2
Bald Cypress	0	0	0	6.104E-05	0
Canadian Wild Rye	0.0135208	0.0059172	0.0057683	0.0049438	0
Common Dandelion	0.0163602	0.0115976	0.0025637	0.0002441	0.0001085
Common Hackberry	0	0	0	0	0
Common Milk Weed	0	0	0	0	0
Common Morning Glory	0.0001352	0.0009467	0.1168082	0.0103149	0.0212674
Curly Dock	0	0	0	0	0.0017361
Eastern Red Cedar	0	0	0	0.0005493	0
Field Nut Sedge	0	0	0	6.104E-05	0
Field Thistle	0	0.0002367	0	0.0103149	0.0053168
Frost Aster	0.0005408	0	0	0.0005493	0
Garlic Mustard	0	0	0	6.104E-05	0.0183377
Japanese Honeysuckle	0	0	0.0040058	0.0005493	0
Kentucky Blue Grass	0.1384532	0.16	0.0775517	0.2739868	0.1736111
Lamb's Quarters	0	0.0002367	0.0014421	0.0005493	0
Northern Red Oak	0.0021633	0.003787	0.0014421	6.104E-05	0
Norway Spruce	0	0	0	0.0005493	0
Old field Goldenrod	0	0	0.0014421	0	0.0001085
Pennsylvania Smartweed	0	0	0	0	0.0001085
Pokeweed	0.0001352	0	0	0.0009766	0.0087891
Prairie Blazing Star	0	0	0.0006409	6.104E-05	0
Switchgrass	0.0654408	0.0766864	0.0001602	0	0
Western Ragweed	0.0012169	0	0	0	0
Yellow Wood Sorrel	0	0.0002367	0.0014421	0	0.0039063
D=	0.2379665	0.259645	0.2132671	0.303833	0.2332899
1-D=	0.7620335	0.740355	0.7867329	0.696167	0.7667101

Table 19. Simpson Index of Species in Meadowbrook Park.

The Simpson index (1-D) of species in No-Mow Zones. The higher the D, the higher the diversity. Otherwise, the 1-D, the higher the number, the lower the diversity.

	M1	M2	M3	M4
Species	(ni/N)2	(ni/N)2	(ni/N)2	(ni/N)2
Big Bluestem	0.065746	0.004444	0.078673	0.025219
Black-Eyed Susan	7.31E-05	0.005625	0.000149	2.18E-07
Bush Clover	7.31E-05	0.006944	0.000149	8.73E-05
Common Goldenrod	0.065746	0.001111	0.133849	0.046162
Compass Plant	7.31E-05	0.0025	0.000149	0.000349
Cream Gentian	0	0.04	0.000149	0.008726
Culver's Root	0	0	0.000149	0
Field Goldenrod	0	0	0.000149	0.001396
Golden Alexander	0	0.000278	0.000149	0.000349
Indian Grass	0.094675	0.011736	0.014872	0.031502
Kentucky Bluegrass	0	0	0.001338	0
Little Bluestem	7.31E-05	0	0	0
Mountain Mint	7.31E-05	0	0	0
Pale Penstemon	0.001169	0	0	8.73E-05
Pasture Thistle	0	0	0	8.73E-05
Prairie Dock	7.31E-05	0.000278	0.000149	8.73E-05
Prairie Sunflower	7.31E-05	6.94E-05	0.000149	0
Purple Coneflower	7.31E-05	0.011736	0.000149	0
Rattlesnake Master	7.31E-05	0.004444	0	0.003141
Rosinweed	0	0	0	0
Stiff Goldenrod	7.31E-05	0	0	0
Sweet Clover	0	0	0	0
Switchgrass	0	0	0	0
Tall Coreopsis	0	0	0	0
Thimble Weed	0	0	0	8.73E-05
Tick Trefoil	7.31E-05	6.94E-05	0	8.73E-05
White Indigo	0	0.011736	0	0.017103
Wild Bergamot	0.001169	0.000278	0.005354	0.000349
Wild Strawberry	0	0.000278	0	8.73E-05
Yellow Coneflower	0.000292	0.000278	0	8.73E-05
D=	0.2296	0.101806	0.235574	0.134995
1-D=	0.7704	0.898194	0.764426	0.865005

Table 20. t-Test: Two-Sample Assuming Unequal Variances Comparing Species Diversity.

t-Test: Two-Sample Assuming Unequal Variances

simpsons diversity

	Meadowbrook	*no mow*
Mean	0.825	0.751
Variance	0.004535758	0.001191
Observations	4	5
Hypothesized Mean Difference	0	
df	4	
t Stat	-2.00060299	
P(T<=t) one-tail	**0.06**	
t Critical one-tail	2.131846786	
P(T<=t) two-tail	**0.12**	
t Critical two-tail	2.776445105	

Simpsons species diversity (1-D) ranged from 0.696 to 0.786 in the No-Mow Zones (Table 18) and averaged 0.750 (Table 20). Simpsons species diversity ranged from 0.764 to 0.898 in Meadowbrook Park (Table 19) and averaged 0.824 (Table 20). Simpson's diversity was not significantly different between the sites ($p = 0.12$).

"Another widely used index is the Shannon index, $H = -\sum ni/N \log eni/N$, which is an approximation of a function originally proposed as a measure of information," (Odum, 1993). Here ni is the coverage of each species of each transect, N is the total coverage of each transect. Tables 21 and 22 show the Shannon index of each transect in No-Mow Zones and Meadowbrook Park.

Table 21. Shannon-Weiner Diversity Index of each transect in No-Mow Zone.

The Shannon-Wiener index of species diversity in No-Mow Zones. The higher the Shannon index, the higher the diversity.

N-M 1	N-M 2	N-M3	N-M4	N-M 5
p sub i	p sub i	p sub i	p sub i	p sub i
0	0	0	-0.0379065	0
-0.2502049	-0.1973038	-0.1957738	-0.186666	0
-0.2630346	-0.2399898	-0.1510457	-0.0649825	-0.0475453
0	0	0	0	0
0	0	0	0	0
-0.0517947	-0.1071151	-0.3669303	-0.2322817	-0.2807716
0	0	0	0	-0.1324189
0	0	0	-0.0879707	0
0	0	0	-0.0379065	0
0	-0.0642213	0	-0.2322817	-0.1909278
-0.0874698	0	0	-0.0879707	0
0	0	0	-0.0379065	-0.2707519
0	0	-0.1746842	-0.0879707	0
-0.3678554	-0.3665163	-0.3560116	-0.3388408	-0.3647786
0	-0.0642213	-0.1242089	-0.0879707	0
-0.1427001	-0.1715749	-0.1242089	-0.0379065	0
0	0	0	-0.0879707	0
0	0	-0.1242089	0	-0.0475453
0	0	0	0	-0.0475453
-0.0517947	0	0	-0.1083042	-0.2219178
0	0	-0.0930709	-0.0379065	0
-0.3487524	-0.3555735	-0.0553095	0	0
-0.1170605	0	0	0	0
0	-0.0642213	-0.1242089	0	-0.1732868
Shannon-Weiner diversity index=				
1.6806672	1.6307375	1.8896618	1.792743	1.7774893

Table 22. Shannon-Weiner Diversity Index of each transect in Meadowbrook Park.

The Shannon index of species diversity in No-Mow Zones. The higher the Shannon index, the higher the diversity.

	M1	M2	M3	M4
Species	P sub i *(ln p sub i)	P sub i *(ln p sub i)	P sub i *(ln p sub i)	P sub i *(ln p sub i)
Big Bluestem	-0.349	-0.1805	-0.3566	-0.2922
Black-Eyed Susan	-0.0407	-0.1943	-0.0537	0
Bush Clover	-0.0407	-0.2071	-0.0537	-0.0437
Common Goldenrod	-0.349	-0.1134	-0.3679	-0.3304
Compass Plant	-0.0407	-0.1498	-0.0537	-0.0744
Cream Gentian	0	-0.3219	-0.0537	-0.2215
Culver's Root	0	0	-0.0537	0
Field Goldenrod	0	0	-0.0537	-0.1228
Golden Alexander	0	-0.0682	-0.0537	-0.0744
Indian Grass	-0.3627	-0.2408	-0.2566	-0.3068
Kentucky Bluegrass	0	0	-0.121	0
Little Bluestem	-0.0407	0	0	0
Mountain Mint	-0.0407	0	0	0
Pale Penstemon	-0.1154	0	0	0.04671
Pasture Thistle	0	0	0	0.04671
Prairie Dock	-0.0407	-0.0682	-0.0537	-0.0437
Prairie Sunflower	-0.0407	-0.0399	-0.0537	0
Purple Coneflower	-0.0407	-0.2408	-0.0537	0
Rattlesnake Master	-0.0407	-0.1805	0	-0.1615
Rosinweed	0	0	0	0
Stiff Goldenrod	-0.0407	0	0	0
Sweet Clover	0	0	0	0
Switchgrass	0	0	0	0
Tall Coreopsis	0	0	0	0
Thimble Weed	0	0	0	-0.0437
Tick Trefoil	-0.0407	-0.0399	0	-0.0437
White Indigo	0	-0.2408	0	-0.266
Wild Bergamot	-0.1154	-0.0682	-0.1913	-0.0744
Wild Strawberry	0	-0.0682	0	-0.0437
Yellow Coneflower	-0.0696	-0.0682	0	-0.0437
Shannon-Weiner Diversity index=	1.80871	2.49078	1.83081	2.09289

Table 23. t-Test on Shannon-Weiner Diversity of No-Mow Zones and Meadowbrook Park.

t-Test: Two-Sample Assuming Unequal Variances

	meadow	no mow
Mean	2.055796769	1.754259781
Variance	0.100752002	0.010256978
Observations	4	5
Hypothesized Mean Difference	0	
df	3	
t Stat	1.827013912	
P(T<=t) one-tail	0.08	
t Critical one-tail	2.353363435	
P(T<=t) two-tail	0.1651607	
t Critical two-tail	3.182446305	

Shannon-Wiener species diversity ranged from 1.63 to 1.89 in the No-Mow Zones (Table 18) and averaged 1.75 (Table 23). Shannon-Wiener species diversity ranged from 1.81 to 2.49 in Meadowbrook Park (Table 22) and averaged 2.05 (Table 23). Shannon-Wiener diversity was not significantly different between the sites ($p = 0.16$).

3.4.4 Species Ecological Value

Tables 24 and 25 show the Coefficient of Conservation of each species of the No-Mow Zones and Meadowbrook Park.

Table 24. Coefficient of Conservation of No-Mow Zones species.

Illinois vascular flora was assigned an integer from 0 to 10, 0 is the lowest ecological value, and 10 is the highest. The symbol "*" means the species is non-native.

Species Name	Coefficient of Conservation
Bald Cypress	7
Canadian Wild Rye	4
Common Dandelion	*
Common Hackberry	3
Common Milk Weed	0
Common Morning Glory	*
Curly Dock	*
Eastern Red Cedar	1
Field Nut Sedge	0
Field Thistle	*
Frost Aster	0
Garlic Mustard	*
Japanese Honeysuckle	*
Kentucky Blue Grass	*
Lamb's Quarters	*
Northern Red Oak	5
Norway Spruce	6
Old field Goldenrod	3
Pennsylvania Smartweed	*
Pokeweed	1
Prairie Blazing Star	6
Switchgrass	4
Western Ragweed	2
Yellow Wood Sorrel	0

Table 25. Coefficient of Conservation of Meadowbrook Park species.

Illinois vascular flora was assigned an integer from 0 to 10, 0 is the lowest ecological value, and 10 is the highest. The symbol "*" means the species is non-native.

Species Name	Coefficient of Conservation
Big Blue Stem	5
Black-Eyed Susan	3
Bush Clover	10
Common Goldenrod	7
Compass Plant	5
Cream Gentian	9
Culver's Root	6
Field Goldenrod	3
Golden Alexander	6
Indian Grass	4
Kentucky Bluegrass	*
Little Bluestem	5
Mountain Mint	4
Pale Penstemon	6
Pasture Thistle	3
Prairie Dock	5
Prairie Sunflower	5
Purple Coneflower	6
Rattlesnake Master	7
Rosinweed	5
Stiff Goldenrod	4
Sweet Clover	*
Switchgrass	4
Tall Coreopsis	4
Thimble Weed	8
Tick Trefoil	5
White Indigo	6
Wild Bergamot	5
Wild Strawberry	2
Yellow Coneflower	4

There were 15 native species and 9 (37.5%) invasive species in the No-Mow Zones; 28 native species and 2 (6.7%) invasive species in Meadowbrook Park. Species in Meadowbrook

Park exhibited a higher total species FQI (26.7) than No-Mow Zones (8.6), Meadowbrook species also exhibited a higher native only FQI (27.6) than No-Mow Zones (10.8). The overall mean conservatism in Meadowbrook (4.87) was also greater than that of the No-Mow Zones (1.75) as was the native species mean conservatism, Meadowbrook (5.2), No-Mow Zones (2.8).

Table 26. Floristic Integrity Assessment Summary Data Comparing Quadrat Cover Data from the Ground Cover in No-Mow Zones and Meadowbrook Park.

	No-Mow Zones	Meadowbrook Park
Total species richness	24	30
Native species richness	15	28
% Adventive (non-native)	37.50%	6.70%
Floristic Quality Index (FQI)	8.6	26.7
FQI (natives only)	10.8	27.6
Mean conservatism	1.75	4.87
Mean conservatism (natives only)	2.8	5.21

3.5 Discussion – Enhancing Existing Habitat

The greater species similarity in Meadowbrook Park indicates the Meadowbrook Park Plant assemblage was more "consistent" or "stable" than the more random species assemblage in the No-Mow Zones. The greater native species richness of Meadowbrook Park indicates that it provides a habitat with more native plants. There were no differences in species diversity indices between the sites. However, this does not mean that the species are the same – regarding diversity.

When the Floristic Integrity Assessment is analyzed we find that not only does Meadowbrook Park contain a greater number of native species than the No-Mow Zones (28 vs.15), it also has a greater native floristic quality index (27.6 vs.10.8). The greater native mean

conservative value also indicates the higher more native importance of the Meadowbrook Park prairie species. Therefore, the species composition of Meadowbrook Park can be used as a reference for future native plants restoration in the Champaign-Urbana vicinity. Especially species with high Coefficients of Conservation (e.g. Bush Clover, Cream Gentian, Rattlesnake Master, Common Goldenrod, Thimble Weed, Golden Alexander, Pale Penstemon, Purple Coneflower, White Indigo) which should be considered as alternatives for habitat restoration.

In addition, as a bee habitat, it is important to provide enough food sources for bee forage during the growing season. Using the species characteristics information in Figure 8 and Figure 9 which show blooming period time-tables and coverage of plants in No-Mow Zones and Meadowbrook Park, respectively, we can evaluate the seasonal species availability.

In the No-Mow Zones there are three pollinator species that bloom in the spring, the total coverage of flowering plants is less than 10%; Thirteen species that bloom in the summer, the total coverage of flowering plants is more than 30%; Nine species that bloom in the fall, the total coverage of flowering plants is nearly 30%.

Based on existing species composition, to enhance No-Mow Zones as bee habitats, the diversity and coverage of bee forage plants in each growing season should be increased. Native spring-blooming species (e.g. Common Periwinkle, Golden Alexander, Pale Penstemon, Spotted Horsemint, Wild Lupine), native summer-blooming plants (e.g. Black-eyed Susan, Compass Plant, Golden Alexander, Mountain Mint, Rattlesnake Master, Yellow Coneflower) and native fall-blooming plants (e.g. Common Goldenrod, Field Goldenrod, Purple Coneflower, Prairie Sunflower) should be added to existing No-Mow Zones to provide food source for bee forage activities. Because flowering plants in No-Mow Zones are scattered, added species should be planted in clusters.

Figure 8. Blooming Period Time-table of Plants in No-Mow Zones.

The blooming time-table and coverage of each plant species in No-Mow Zones. The length and color of the bars above corresponded with blooming period and flower color of each species. The percentage number represents coverage percentage of each species of all four transects in No-Mow Zones. Species with coverage less than 1% were accounted as 1%. Non-flowering plants were shown without color bars.

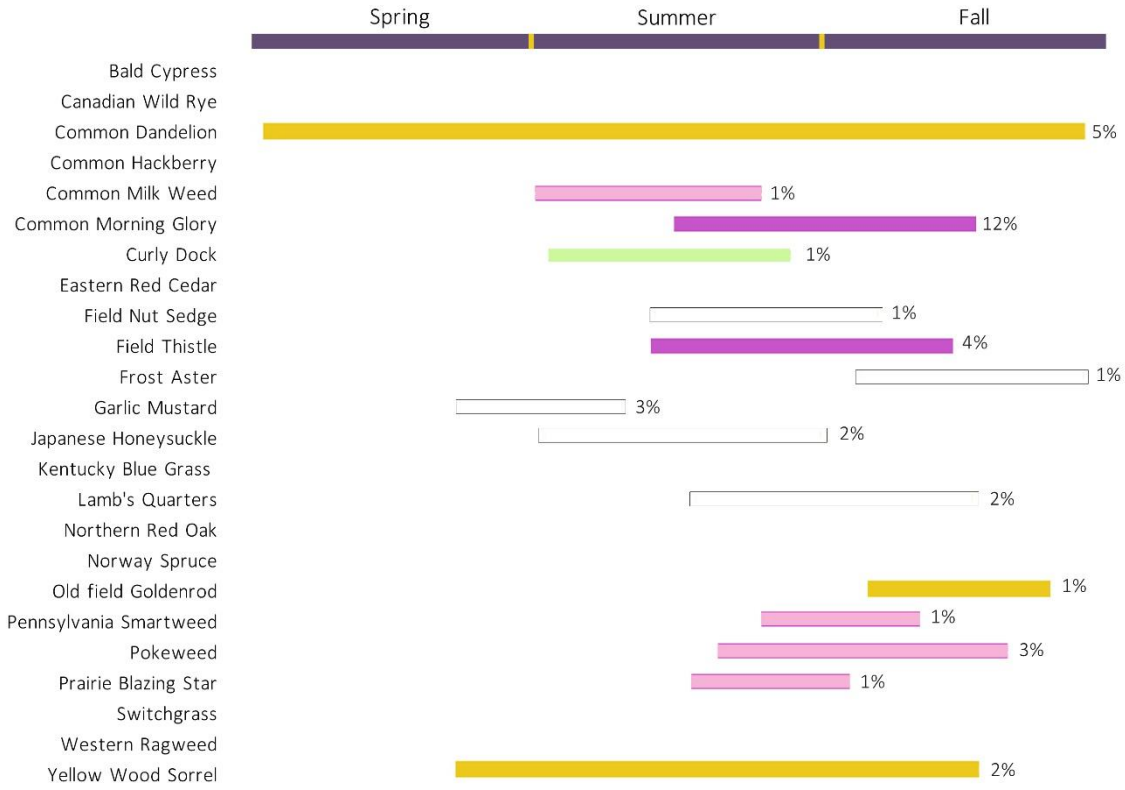
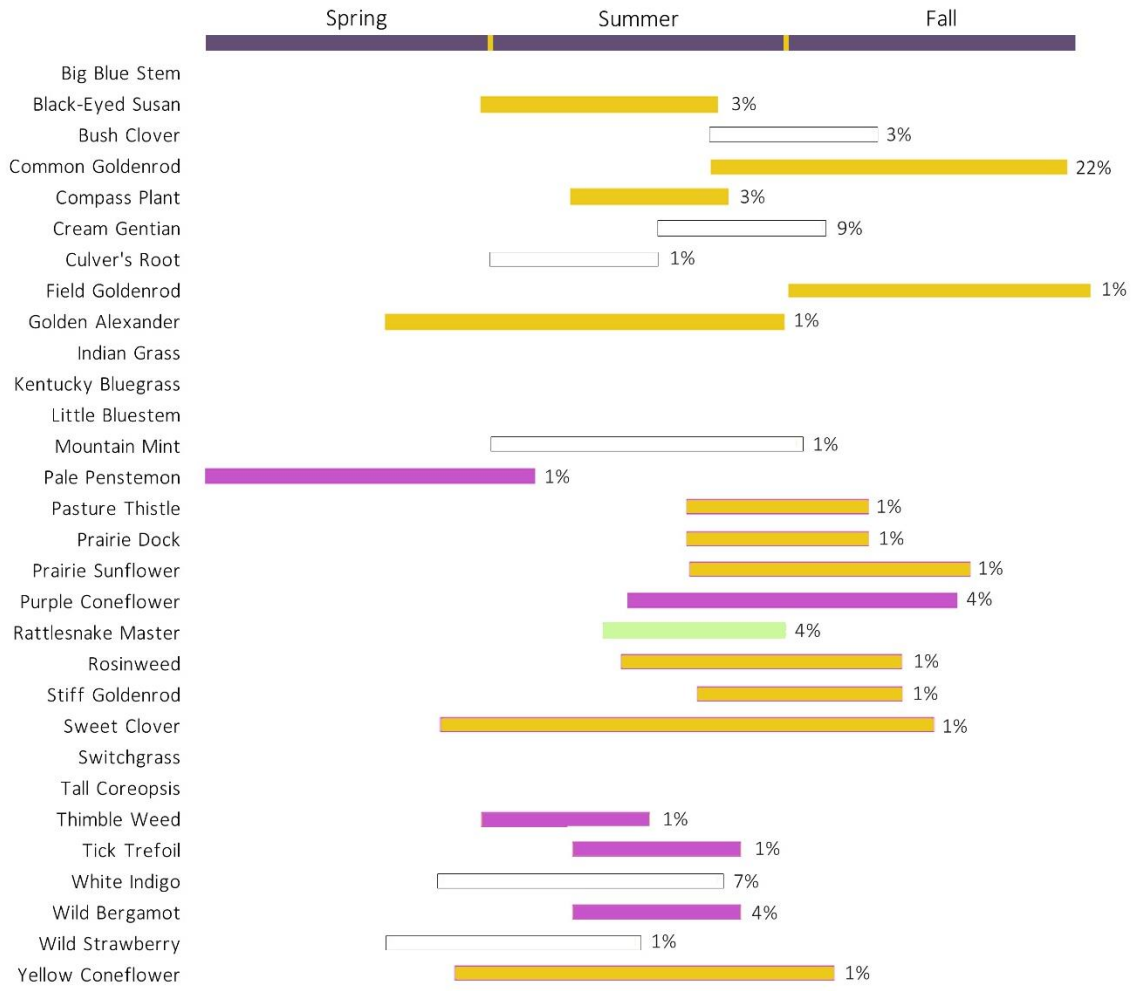


Figure 9 shows blooming time-table and coverage of each plant species in Meadowbrook Park. There are six different pollinator plants blooming in spring, the total coverage of flowering plants is less than 10%, and there is only one species Pale Penstemon (frequency 10%, coverage 1%) blooming in early spring; Twenty-two plants blooming in summer, the total coverage of flowering plants is more than 70%, and the color of flowers is diverse; Twelve plants blooming in fall, the total coverage of flowering plants is nearly 40%, the color of flowers is diverse.

Meadowbrook Park has great potential to provide more food sources for bee forage. Based on the species composition, it indicates that early spring forage species are missing. To enhance Meadowbrook Park as a bee habitat, spring-blooming especially early spring-blooming plants (e.g. Spotted Horsemint, Wild Lupine) should be added, and the coverage of existing spring species (Golden Alexander, Pale Penstemon, Wild Strawberry) should be increased.

Figure 9. Blooming period time-table of plants in Meadowbrook Park.

The blooming time-table and coverage of each plant species in Meadowbrook Park. The length and color of the bars above corresponded with blooming period and flower color of each species. The percentage number represents coverage percentage of each species of all four transects in Meadowbrook Park. Species with coverage less than 1% were accounted as 1%. Non flowering plants were shown without color bars.



CHAPTER 4: CREATING NEW HABITAT – SITE SELECTION

Site selection for developing a new pollinator-enhancement habitat should include a thorough assessment of land use, geographic information (including aspect, slope, and soil composition), and a social behavior map.

4.1 Site Description

The research focused on the main campus of the University of Illinois at Champaign-Urbana. The area studied ranged from University Avenue on the north to St. Mary's Road on the south, and occupied 573 acres of land. The University of Illinois at Urbana-Champaign is located in east central Illinois in Champaign County. The Campus Master Plan Update of March 2007 was provided by Sasaki Associates and Facilities & Services and used in the analysis.

4.2 Site Analysis

Given that the pollinator habitats are proposed for use on campus, campus land use and human traffic patterns are crucial considerations for site selection.

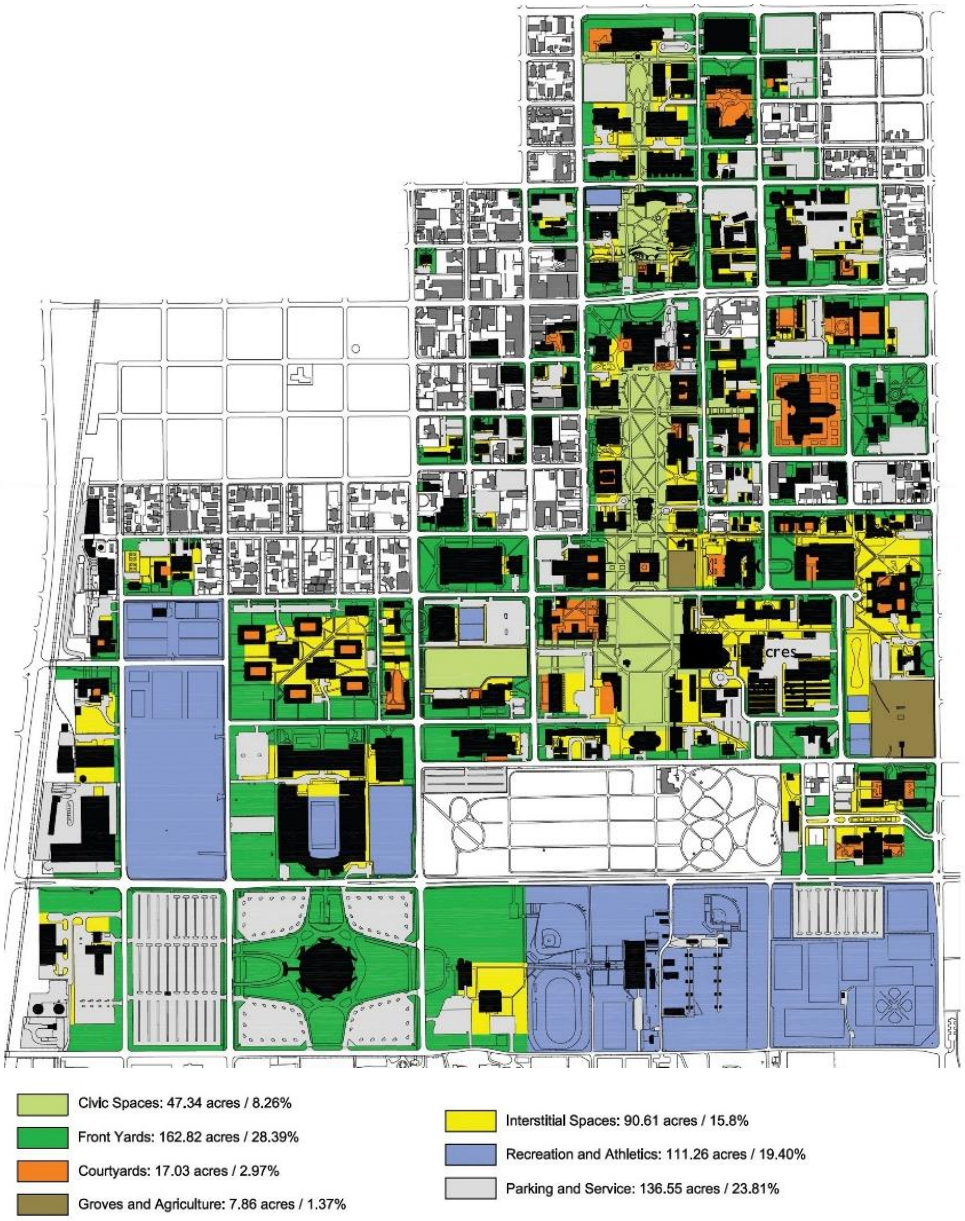
1. Land use

The campus land use map provided by Sasaki Associates (Figure 10), showed that of the 573 acres of main campus land included civic spaces, front yards, court yards, groves and agriculture land, interstitial spaces, land for recreation and athletics, and land for parking and service. Pollinator habitats should not be located in land with special function uses (e.g. recreation, athletics, parking, service), formal and public areas (e.g. civic spaces, front yards), private spaces (e.g. court yard) and preserved land (e.g. historical protective field, forest preserve). Compared to other types of land, interstitial spaces are empty spaces without major

functional uses, neither social nor private, and less formal. Because there is less human use, it would be best to use interstitial spaces as bee habitats.

Figure 10. Land Use Map of University of Illinois. (Image source: http://www.uocpres.uillinois.edu/resources/uiucplan).

This is the land use map of University of Illinois. Campus land uses are categorized as civic spaces, front yards, court yards, groves and agriculture, interstitial space, recreation and athletics, and parking and service. Civic spaces are social spaces that are generally open and accessible to people. Front yards are portions of land between the street and the front of the building. Courtyards are enclosed areas, and often serve as primary meeting places. Interstitial spaces are empty space or gaps between built spaces. Grove and agriculture land is preserved forest and agriculture land. Recreation and Athletics include playing fields and areas for public recreation, and parking and service include public and private parking and areas, and service included areas used for operations and maintenance.



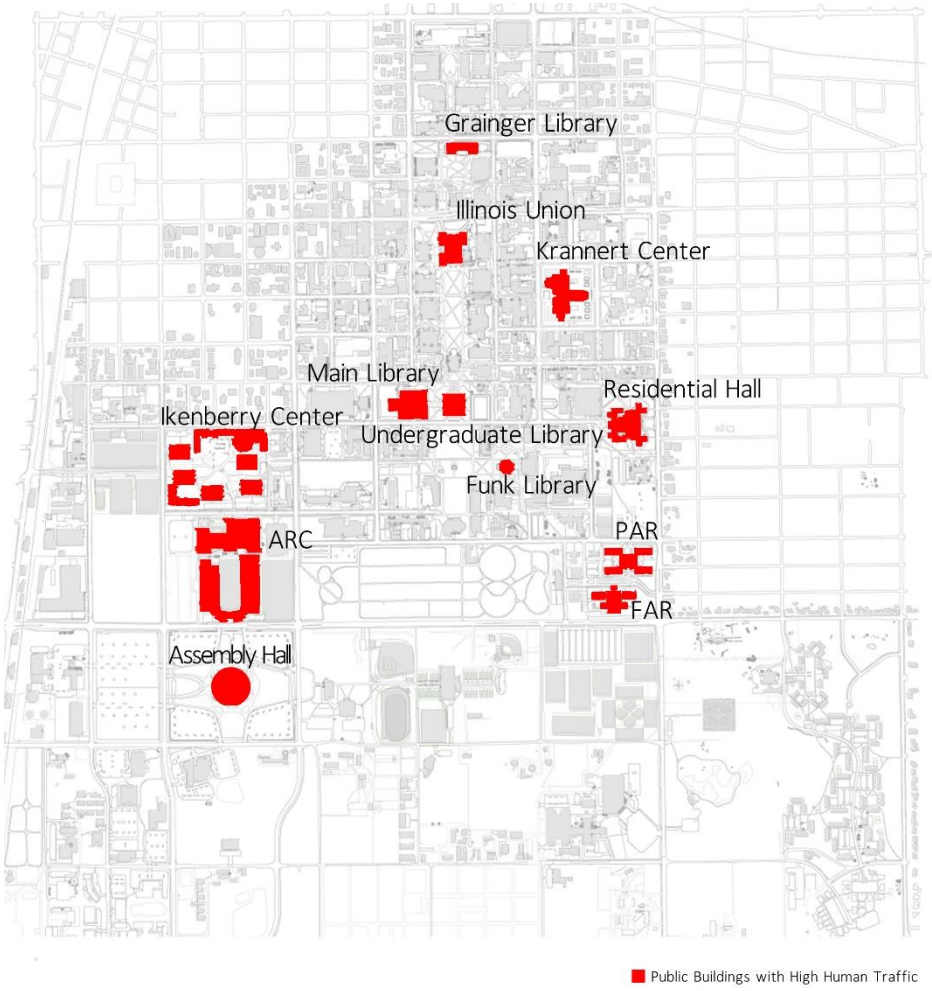
2. Human traffic patterns

The next stage entailed a human traffic map of the University of Illinois. The guideline for site selection specified areas with low human traffic rates. Therefore the utilization rate of buildings and roads were crucial factors in the design.

The building utilization map (Figure 11) indicates unfavorable areas marked in red. Red represents public buildings with high human traffic, such as libraries, activities and recreation centers, residence halls, and research buildings. Interstitial spaces and yards around high-usage buildings are also high human traffic areas, these areas are unfavorable for bee habitats.

Figure 11. Public Architecture with High Human Traffic.

The building utilization map (Figure 11) indicates public buildings with high human traffic marked in red, such as libraries, activities and recreation centers, residence halls, and research buildings. Interstitial spaces and yards around high-usage buildings are also high human traffic areas. Areas marked in read means unfavorable sites for bee habitats.



In terms of road usage, this study takes frequently-used road intersections, bus stops, and bus routes into account. With regard to road intersections, the Campus Traffic Report indicates the ten busiest intersections in terms of pedestrian, bike and automobile volumes which are indicated with black dots on map (Figure 12). The Champaign-Urbana Mass Transit District system (MTD) is the largest public transportation system in Champaign-Urbana region and the primary transportation system of the University of Illinois. Routes and bus stops are considered

to be important indicators of human traffic (UIUC transportation guide). The MTD route analysis map below (Figure 12) shows the busiest bus stops as being marked with black dots.

In figure 13, MTD routes are marked using red lines. The thickness of the red line represents MTD route usage. The thicker the line, the more usage it has. High-use walkways are marked in pink. Areas surrounded by routes marked with thick red line and pink are unfavorable for bee habitats.

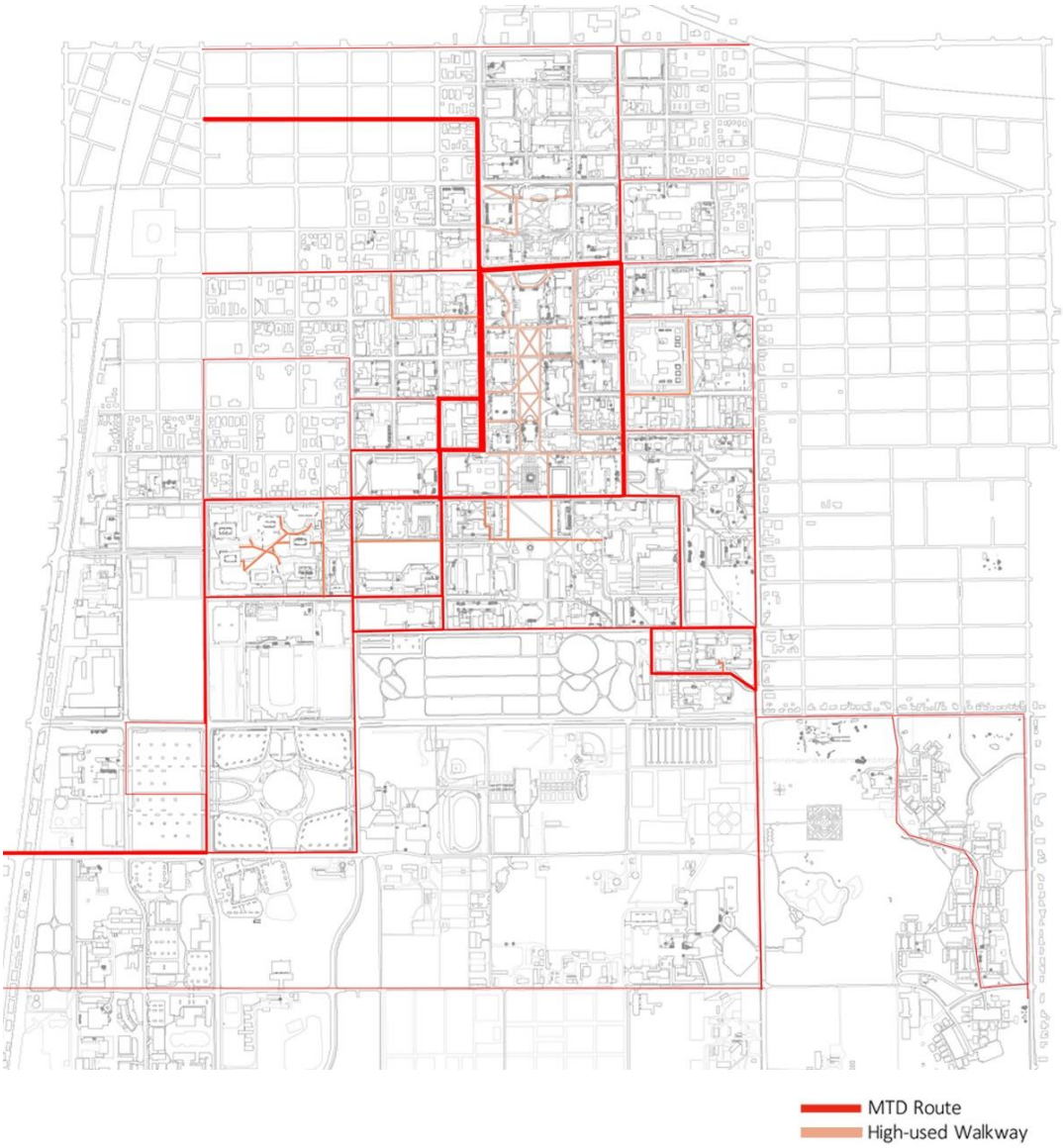
Figure 12. Crossings and Bus Stops with High Human Traffic.

The ten busiest intersections in terms of pedestrian, bike and automobile volumes, busiest bus stops at campus are marked with black dots. Areas near black dots are unfavorable for bee habitats.

Synthesis of the human traffic analysis above, indicates that south campus has a comparatively low human traffic rate, which makes that area ideal for new bee habitats.

Figure 13. Route with High Human Traffic. MTD Routes are Marked Using Red Lines.

The thickness of the red line represents MTD route usage. The thicker the line, the more usage it has. High-use walkways are marked in pink. Areas surrounded by routes marked with thick red line and pink are unfavorable for bee habitats.



4.3 Site Selection

Overlaying interstitial spaces area with low human traffic, Figure 14 shows the optimum sites for bee habitats marked in yellow.

Figure 14. Proposed New Bee Habitats.

Area marked in yellow are field with informal use and low human traffic. It is optimum for bee habitats.

Results indicated that new bee habitats should be located on south campus. Potential sites could be in the vicinity of the College of Agriculture, Consumer, and Environmental Science (ACES) and the north part of the arboretum. The distribution of existing No-Mow Zones and

prairie zones showed that the area on the corner of West Florida Avenue and South Lincoln Avenue was an ideal location for a bee habitat network center. This area was 3.32 acres in size. This location was distant from busy transportation zones. There was an existing 2.06 acre prairie zone nearby. These two zones have the potential to support a bee hive. The honeybee flight distance experiment reflects that the flight distance zone of bees which ranges from 500 feet to 4 miles. When the flight distance is kept under two miles, flight speed and efficiency is comparatively high. (Hagler, 2011). Efficiency decreases with increasing flight distance (Figure 15).

Figure 15. Flight Distance & Flight Speed of Honey Bee.

Using the chosen site as the center, the radius of the concentric circles represent 500 feet, 0.25 mile, 0.5 mile, 1 mile, and 2 miles, respectively. The circle with the radius of 0.5 mile covers most of the bee habitat network area.

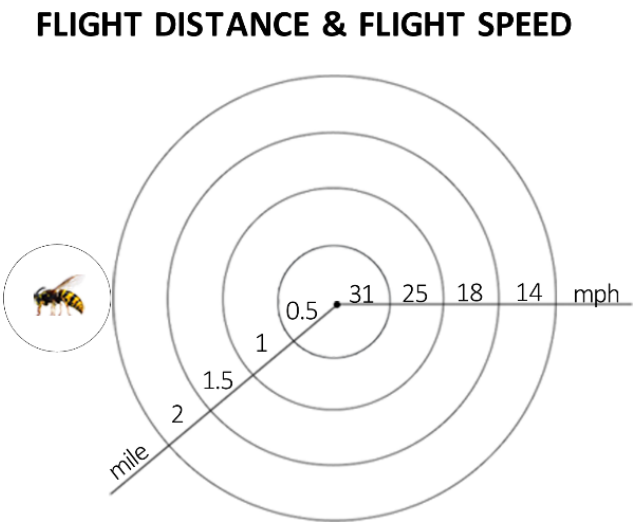


Figure 16. Bee Habitats Network on Campus.

Composite analysis of bee habitat network overlaying interstitial spaces with low human traffic. Areas marked in yellow show the optimum sites for bee habitats. Synthesizing the optimum bee habitat locations (marked in yellow) and distribution of existing prairie zones and no-now zones (marked in red). The center of the concentric circles represents the bee habitat network center, and integrates bee foraging activities with effective flight distance.

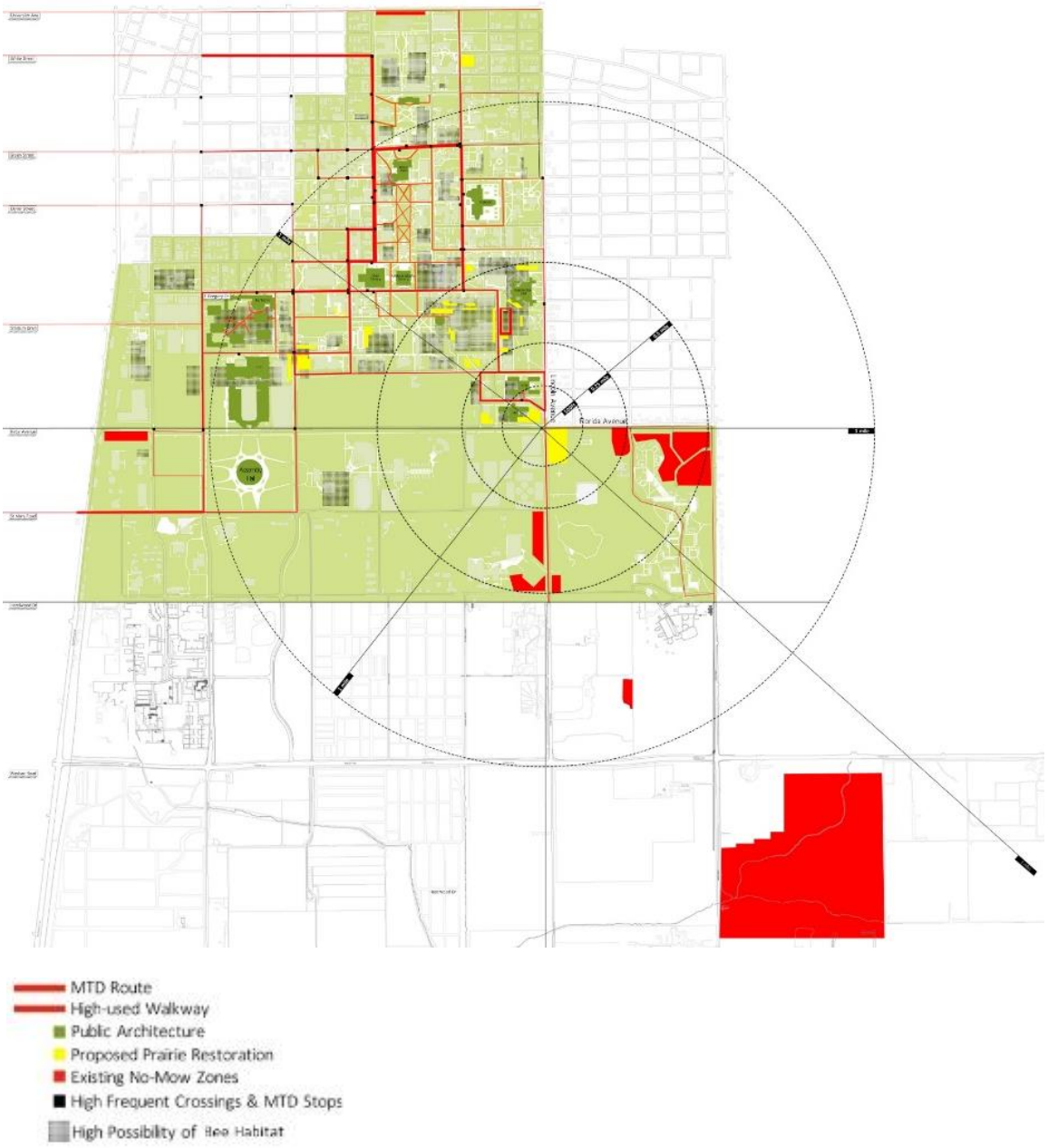
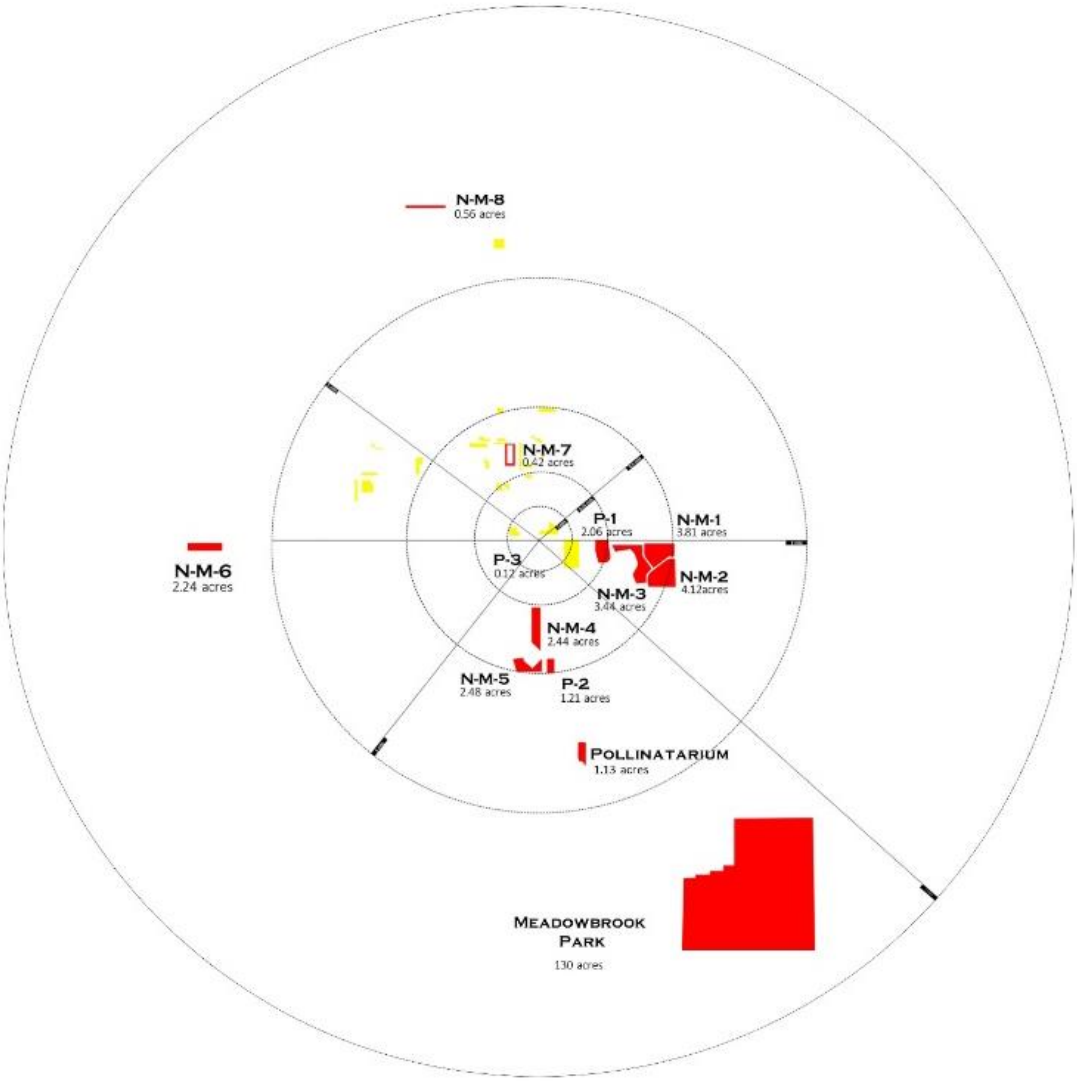


Figure 17. Integrated Bee Habitats System within Bee's effective Flight Distance.

The bee habitat network, with existing No-Mow Zones and prairie zones marked in red and proposed bee habitats in yellow. This network ensures that bees can find sufficient food resources with high working efficiency. The sites can also have an educational purpose without interfering with daily activities on campus.



CHAPTER 5: DESIGN PROPOSAL

This section includes four proposed site designs, including two proposed site designs for new bee habitats, an enhancement plan for an existing No-Mow Zone and an enhancement plan for Meadowbrook Park.

5.1 Habitat Network Center

The first design is the proposed “Habitat Network Center”. It is located on the corner of West Florida Avenue and South Lincoln Avenue. As a bee habitat network center, in addition to meeting the goal of providing year-round food for the bees, this garden design is responsive to sustainable design principles and the needs of visitors. The intended audience for this bee garden is diverse (i.e., UIUC students and researchers, farmers nearby, family groups, Master Gardeners).

This proposed “habitat network center” is composed of three parts. Entering from north entrance, the first part is composed of four rectangular plant clusters (Wild Lupine, Pale Penstemon, Bee Balm, Black-eyed Susan) which define the space and provide an inviting public programming area, the height of these four species are 1’-2’, the low height clusters would not block views of visitors passing through. The second part is densely planted with native prairie plant clusters, composed of Cream Gentian, Common Goldenrod, White Indigo, Wild Bergamot, Wild Strawberry, Yellow Coneflower, Purple Coneflower, Golden Alexander, Mountain Mint, Stiff Goldenrod. The third part, an open space, provides a central gathering area. On the north, there are three planted Basswood trees, under one basswood, a concrete bee watering pool connected to the irrigation system provides a bee-friendly water source. A bee hive on the northwest corner is accessible from the walking path and visible to passersby from outside the garden. The selected species were mostly chosen from the Meadowbrook Park plant list. Several

other species Bee Balm (summer-blooming), Common Periwinkle (spring-blooming), Wild Lupine (spring-blooming) will be added to ensure that there will be sufficient food resources for bees during the entire growing season. The design ensures that at least three different species bloom during each season. Figures 18, 19 and 20 show the site plan, color palette and perspective viewpoints of this “Habitat Network Center”.

Figure 18. Site Plan of "Habitat Network Center".

This design is composed of three parts. Entering from north entrance, although visitors may circulate at will, the storyline begins at the first part which composed of four quadrangle plant clusters, functioned as passageway, then run clockwise to the second part which densely planted native plants as a plants demonstration, then the third part, an open space with bee hives and a bee-friendly water source. A bee hive (marked in yellow) and a concrete watering pool (marked in black) connected to the irrigation system provides a bee-friendly water source.

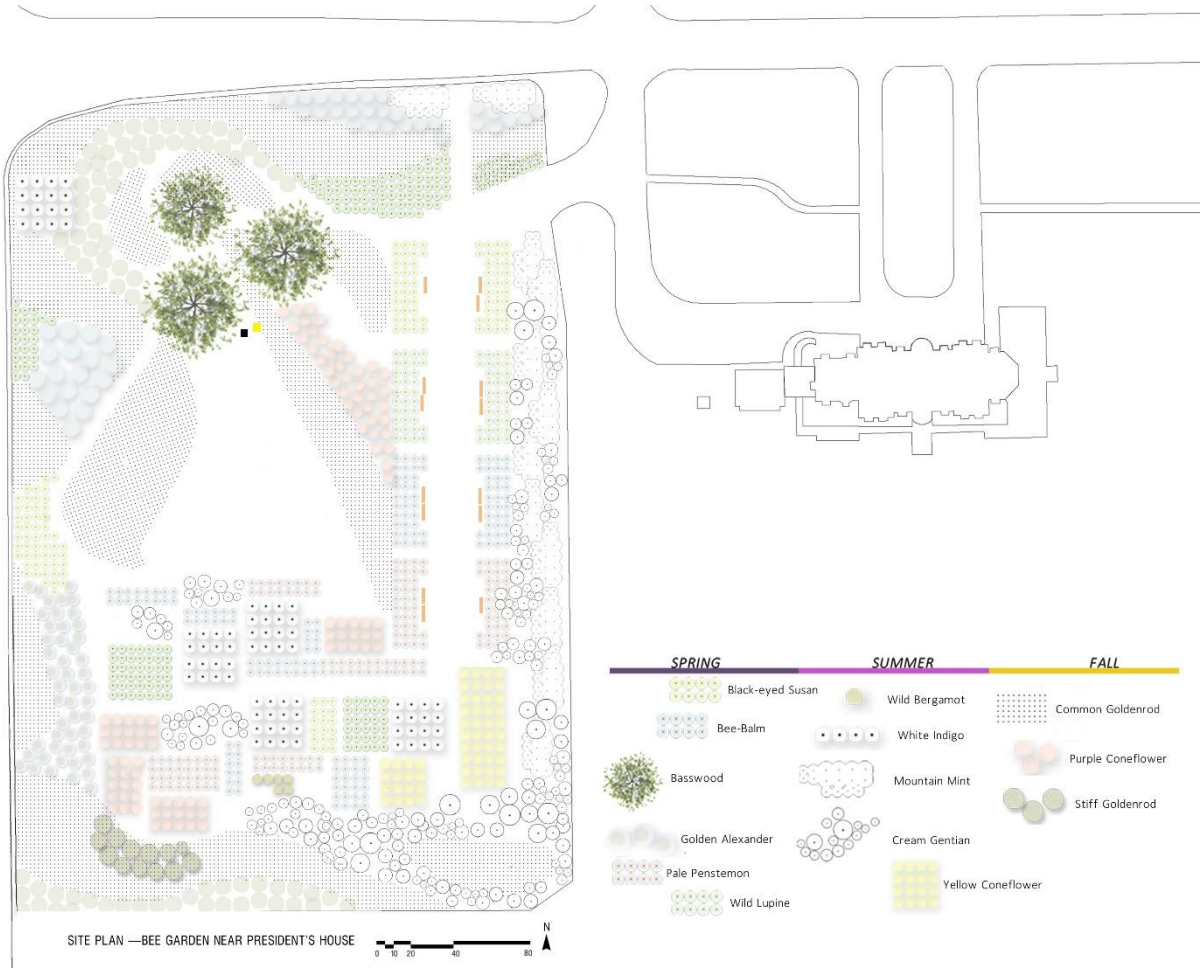


Figure 19. Color Palette of "Habitat Network Center".

This color palette illustrates how flowers' color change in spring, summer and fall. There should be diverse species and diverse color during each season.

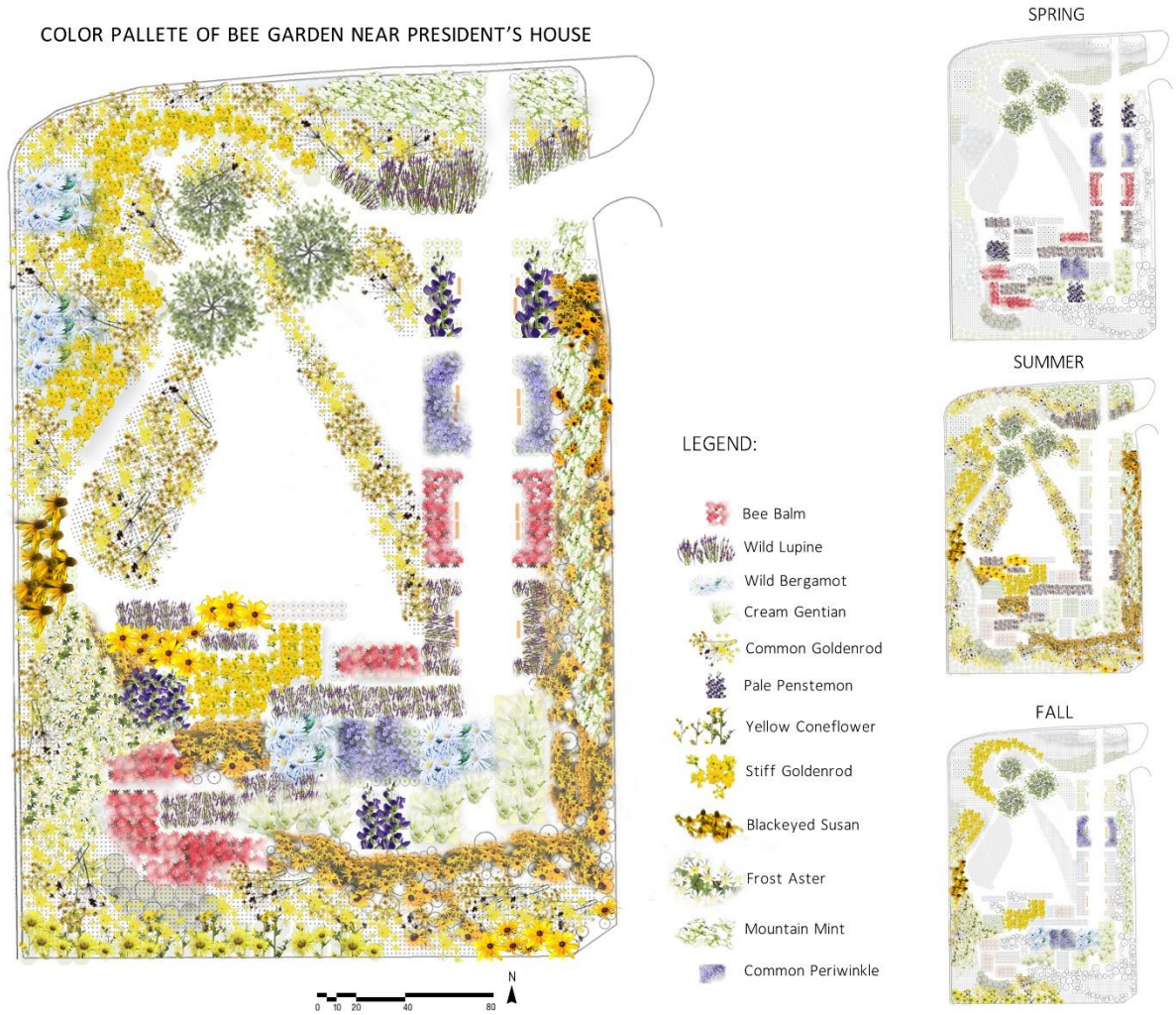


Figure 20. Perspective of "Habitat Network Center".

"Habitat Network Center", located on the corner of West Florida Avenue and South Lincoln Avenue, 3.05 acres.

5.2 ACES Bee Habitat

The Second design is located in the College of Agriculture's, Consumer, and Environmental Science (ACES) area. Within this area, there are three potential sites: 1) north of the parking lot near the Plant Sciences Lab; 2) west of the greenhouse at the Plant Science Lab; and 3) another location west of the National Soybean Research Center (Figure 21). The sizes of the three sites are: 0.10 acres, 0.35acres and 0.5 acres. In comparison with the first site, the habitats within the ACES complex are small demonstration areas located in interstitial spaces.

These three sites located within the ACES area, will serve an educational purpose. They will provide ACES students with opportunities to study bee habitat function and design. Within ACES bee habitat, accessible interpretive graphics and identification labels would inform visitors of species diversity, bee diversity, bee behavior, bee keeping, pollination, etc. These three sites are proposed to be densely planted with native prairie plant clusters, composed of Cream Gentian,

Common Goldenrod, White Indigo, Wild Bergamot, Wild Strawberry, Yellow Coneflower, Purple Coneflower, Golden Alexander, Mountain Mint, and Stiff Goldenrod. Within these three areas, a bee hive on the west of greenhouse is accessible from the walking path. Figures 22, 23 and 24 show the site plan, color palette and perspective viewpoints of the ACES bee habitat.

Figure 21. Site Plan of ACES Bee Habitat.

Within the ACES area, there are three potential sites: 1) north of the parking lot near the Plant Sciences Lab; 2) west of the Greenhouse at the Plant Science Lab; 3) west of the National Soybean Research Center. The sizes of the three sites are: 0.10 acres, 0.35acres and 0.5 acres. In comparison with the first site, the habitats within the ACES complex are small demonstration areas located in interstitial spaces.

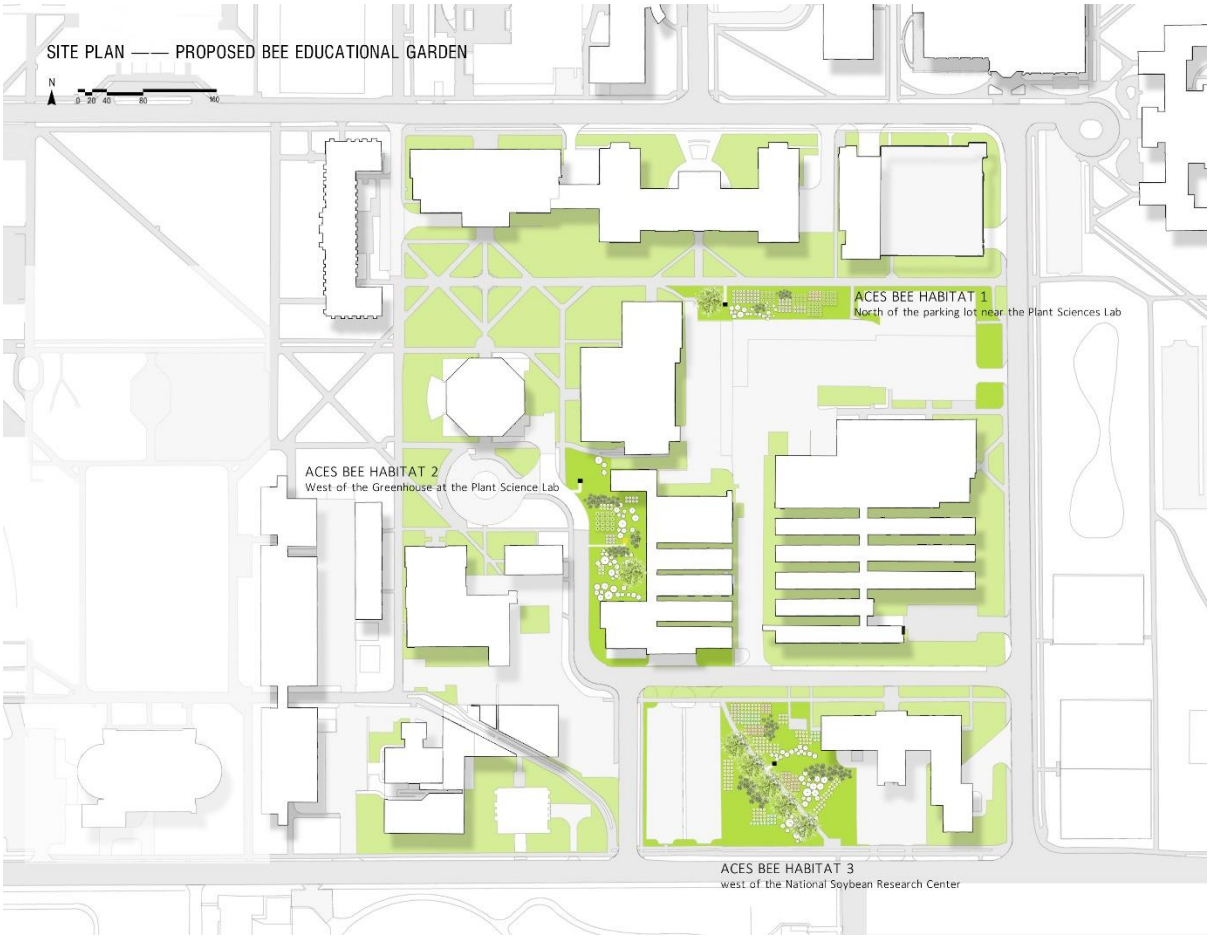


Figure 22. Detailed Site Plan of ACES Bee Habitat.

These three sites are proposed to be densely planted with native prairie plants clusters, composed of Cream Gentian, Common Goldenrod, White Indigo, Wild Bergamot, Wild Strawberry, Yellow Coneflower, Purple Coneflower, Golden Alexander, Mountain Mint, Stiff Goldenrod. Within these three areas, a bee hive (marked in yellow) on the west of greenhouse is accessible from walk path. Each site has a concrete watering pool (marked in black) connected to the irrigation system provides a bee-friendly water source.

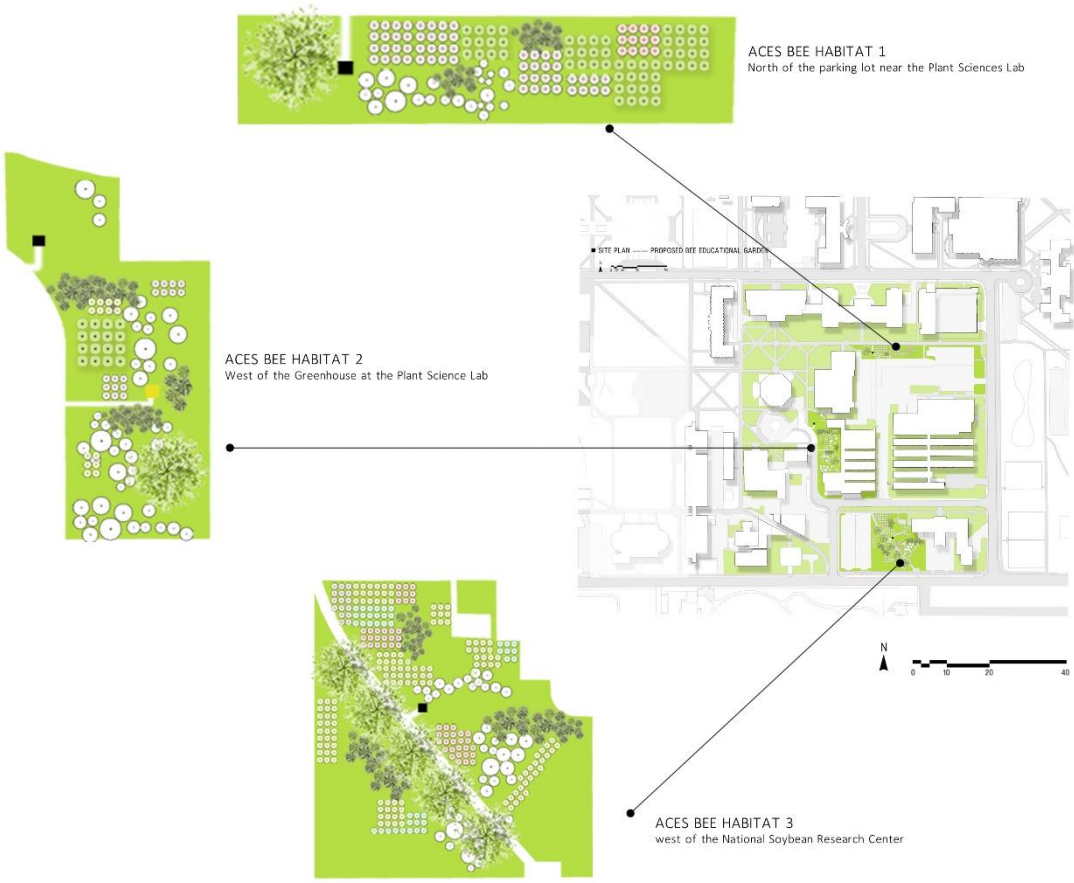


Figure 23. Color Palette of ACES Bee Habitat.

This color palette illustrates how flowers' color change in spring, summer and fall. There should have diverse species and diverse color in each season.

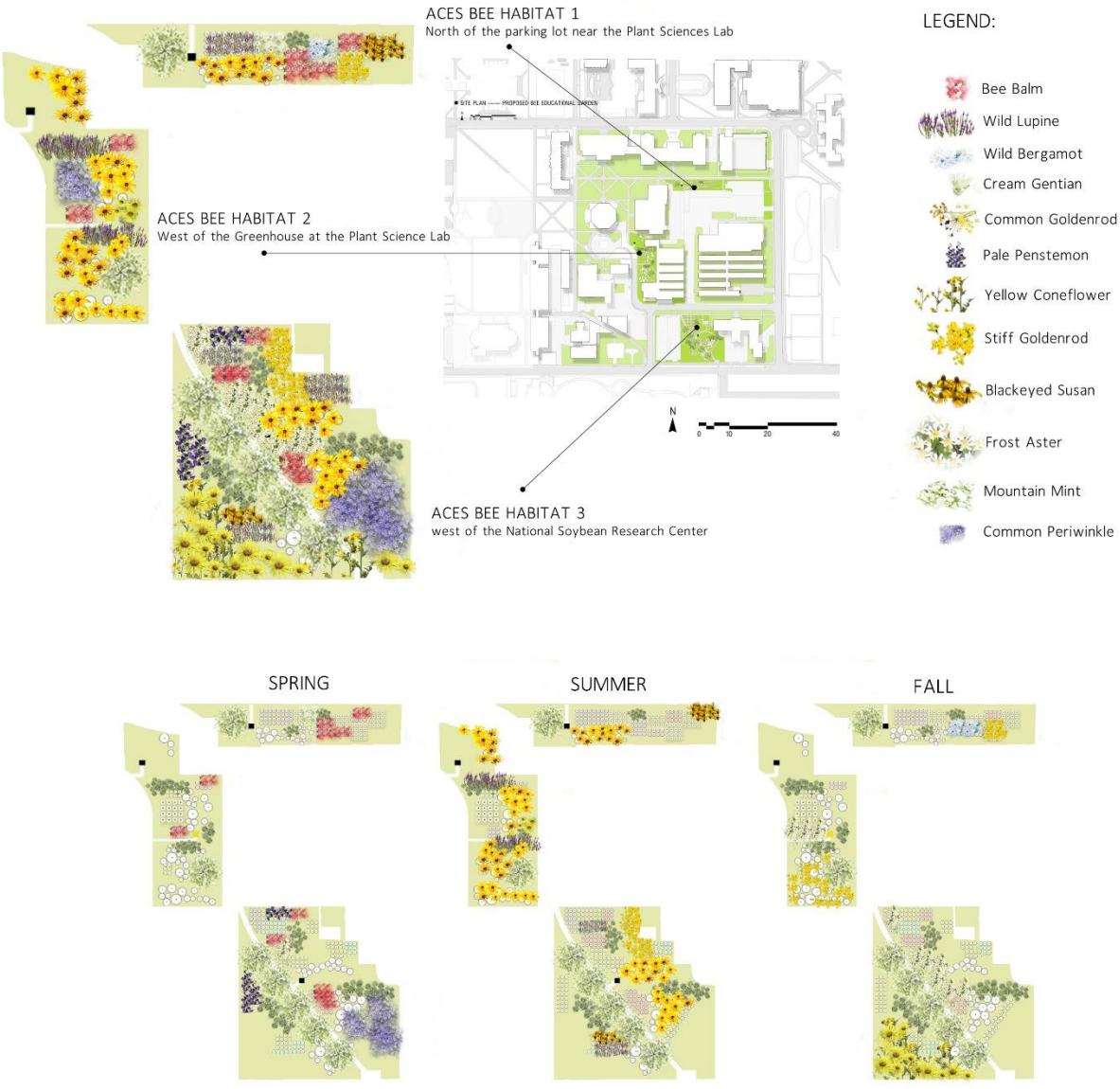


Figure 24. Perspective of ACES Bee Habitat.

ACES Bee Habitat 2, located west of the Greenhouse at the Plant Science Lab, 0.35 acres. ACES Bee Habitat 2 is an educational bee garden.

5.3 No-Mow Zone Enhancement

My previous survey (Chapter 3) found that the species in the No-Mow Zones could not support foraging activities of bees. Based on existing species composition, to enhance No-Mow Zones as bee habitats, the coverage of bee plants in each growing season should be increased to at least 40%. This will add a variety of native bee plants species that bloom in each season, especially in in the spring. Because flowering plants in No-Mow Zones are scattered, new planted plants should be planted in clusters.

My No-Mow Zone designs are intended to transform the 100-foot border of the No-Mow Zones into bee habitats, by including plant species that will support the activities of bees during

the growing season. Border transformations will still allow the existing No-Mow Zones to function as energy saving areas on campus while also enhancing the areas for use as bee foraging habitat. The site design proposes a walkway within both the No-Mow Zones and the bee habitat border to allow for pedestrian traffic and mowing access. Figures 25, 26 and 27 show the site plan, color palette and the perspective viewpoints of the No-Mow Habitat near the Orchard Downs Community.

Figure 25. Site Plan of No-Mow Zone Enhancement at Orchard Downs.

Located at the corner of W. Florida Ave. and S. Race St., the Orchard Downs design proposes to transform the 100-foot border of the No-Mow Zones into an area planted with bee forage plants in clusters. Combined with existing plants in the No-Mow Zone, this area will support the activities of bees during the growing season.

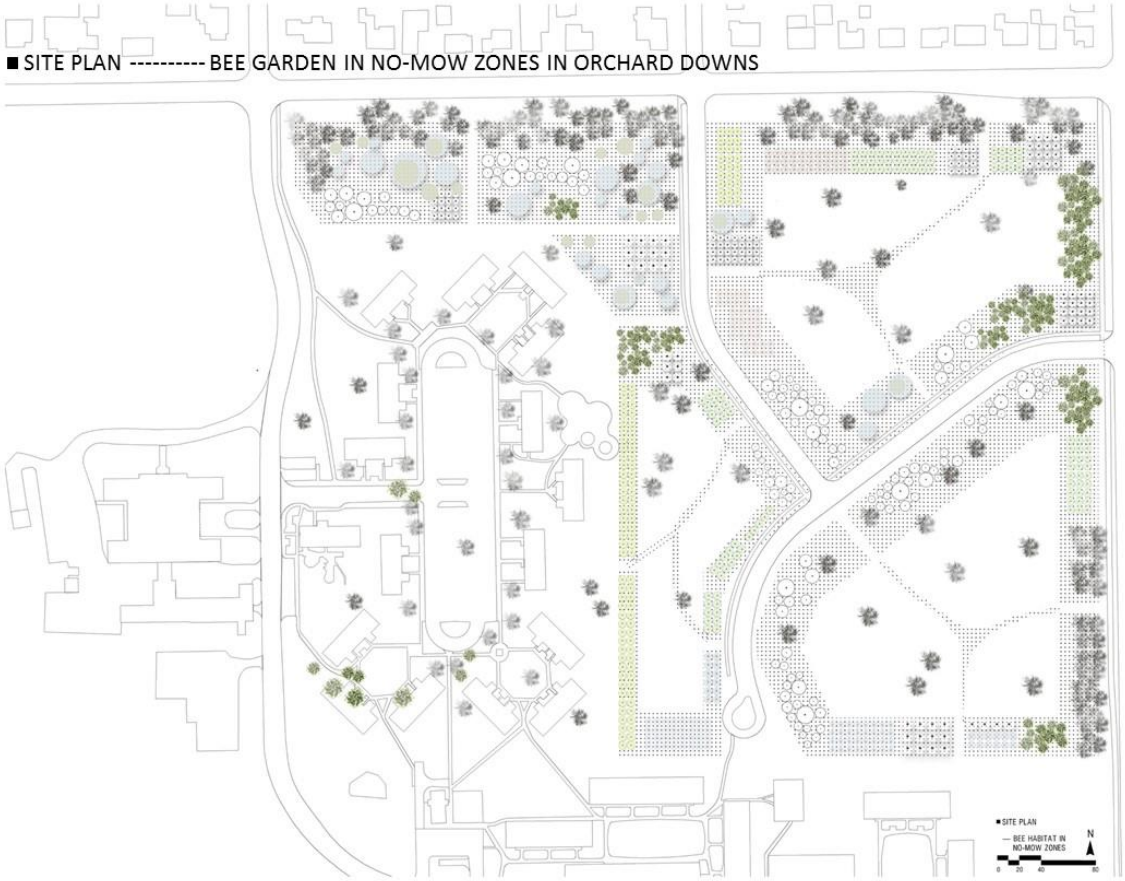


Figure 26. Color Palette of No-Mow Zone Enhancement Plan at Orchard Downs.

This color palette illustrates how flower colors change in spring, summer and fall at Orchard Downs. There will be diverse species and diverse colors in each season.

Figure 27. Perspective of No-Mow Zone Enhancement Plan at Orchard Downs.

No-Mow Zone Enhancement Plan at Orchard Downs, located at the corner of W. Florida Ave. and S. Race St., 7 acres.

5.4 Meadowbrook Park Enhancement

Meadowbrook Park, has great potential to function as a food source for bee forage. To enhance Meadowbrook Park as a bee habitat, especially early spring-blooming plants (e.g. Spotted Horsemint, Wild Lupine, Prairie Phlox, Cream Wild Indigo) and fall blooming plants (e.g. Cardinal Flower, False Boneset, Michigan Lily) should be added. The coverage of existing spring species (Golden Alexander, Pale Penstemon, Wild Strawberry) should be increased, especially species with high Coefficients of Conservation (e.g. Bush Clover, Cream Gentian, Rattlesnake Master, Common Goldenrod, Thimble Weed, Pale Penstemon, Purple Coneflower).

The Meadowbrook Park design can serve as an example of how existing prairie zones can be enhanced by adding plants which flower during the spring to ensure that there are enough plants blooming during the entire growing season. Based on the existing plant composition of Meadowbrook Park (Figure 28) and the recommended native bee forage plant list (Ley, 2012), I listed the recommend species indicated in figure 29.

Figure 28. Blooming period time-table of plants in Meadowbrook Park. (Same as Figure 9)

The blooming time-table and coverage of each plant species in Meadowbrook Park. The length and color of the bars above corresponded with blooming period and flower color of each species. The percentage number represents coverage percentage of each species of all four transects in Meadowbrook Park. Species with coverage less than 1% were accounted as 1%. Non flowering plants were shown without color bars.

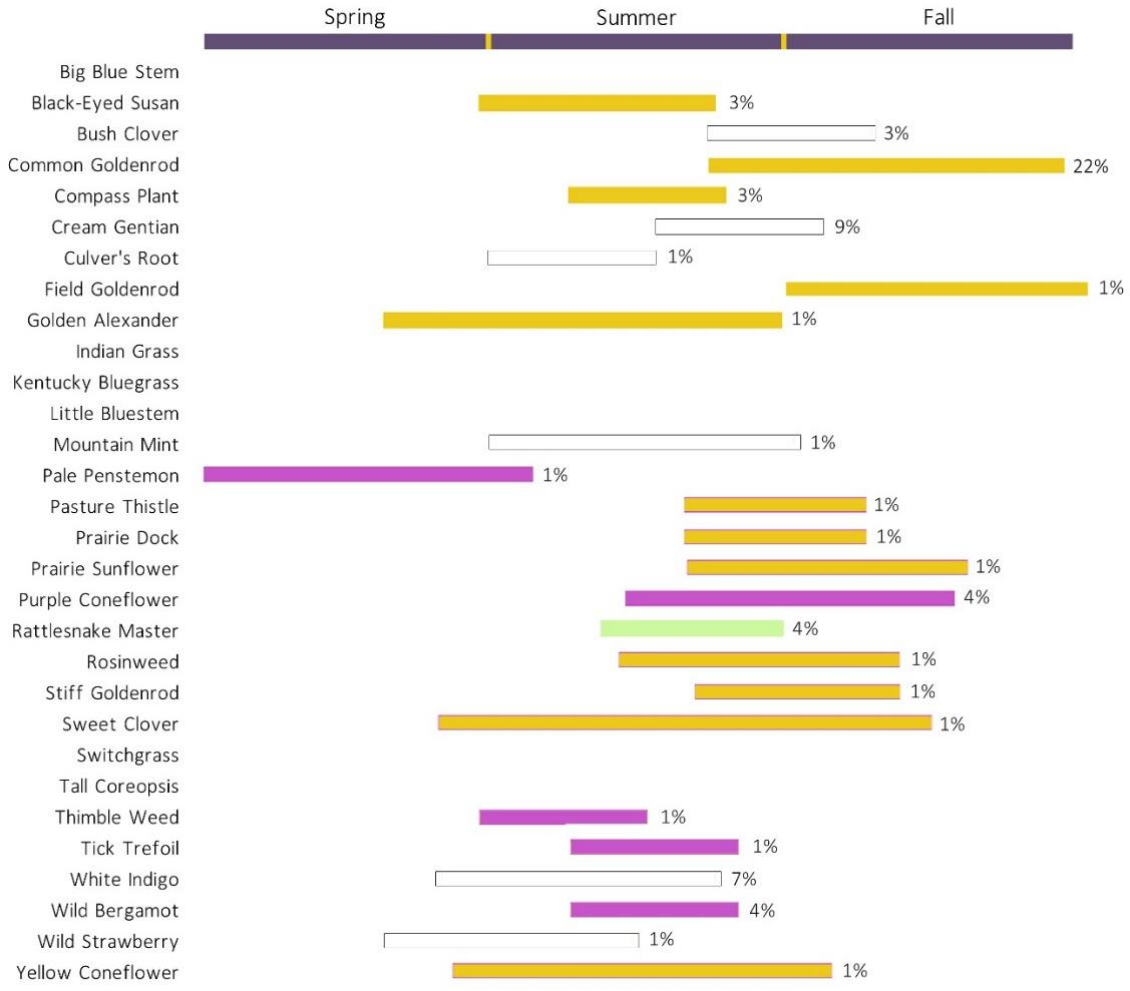
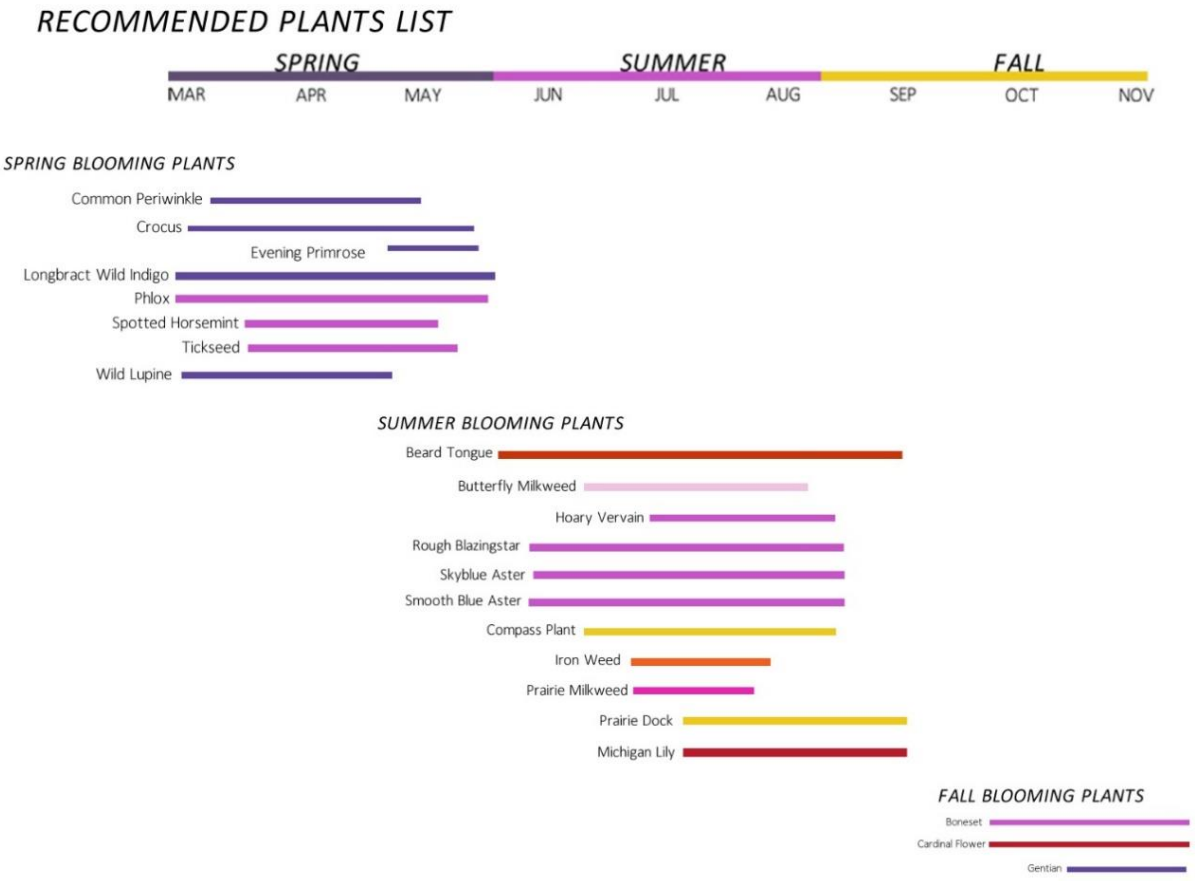


Figure 29. Recommended Plants List for Meadowbrook Park.

The recommended native bee forage plants list (Ley, 2012). This list provides Illinois species that bloom throughout the entire honey bee yearly foraging season.



The species in Figure 29 were added to the Meadowbrook Park design to support bee forage activities throughout the entire yearly honey bee foraging season and to increase the floristic quality. Based on my findings I added spring-blooming plants (e.g. Spotted Horsemint, Wild Lupine, Prairie Phlox, Cream Wild Indigo) and fall-blooming plants (e.g. Cardinal Flower, False Boneset, Michigan Lily) to the Meadowbrook Park species list. These six species are all native plants with high coefficient of conservation, Spotted Horsemint (5), Wild Lupine (8), Prairie Phlox(7), Cream Wild Indigo (9), Cardinal Flower (6), False Boneset (6), Michigan Lily(6). Table 25 shows the Coefficients of Conservation of the current and proposed Meadowbrook Park

species. Table 27 compare the present species floristic quality assessment with the floristic quality assessment of my proposed design recommendation.

Table 27. Coefficient of Conservation of Proposed Meadowbrook Park Species.

Species highlighted in green are the proposed species, other species are current species of Meadowbrook Park. Illinois vascular flora was assigned an integer from 0 to 10, 0 is the lowest ecological value, and 10 is the highest. The symbol "*" means the species is non-native.

Species Name	Coefficient of Conservation
Big Blue Stem	5
Black-Eyed Susan	3
Bush Clover	10
Cardinal Flower	6
Common Goldenrod	7
Compass Plant	5
Cream Gentian	9
Cream Wild Indigo	9
Culver's Root	6
False Boneset	6
Field Goldenrod	3
Golden Alexander	6
Indian Grass	4
Kentucky Bluegrass	*
Little Bluestem	5
Michigan Lily	6
Mountain Mint	4
Pale Penstemon	6
Pasture Thistle	3
Prairie Dock	5
Prairie Phlox	7
Prairie Sunflower	5
Purple Coneflower	6
Rattlesnake Master	7
Rosinweed	5
Spotted Horsemint	5
Stiff Goldenrod	4
Sweet Clover	*
Switchgrass	4
Tall Coreopsis	4
Thimble Weed	8
Tick Trefoil	5
White Indigo	6
Wild Bergamot	5
Wild Lupine	8
Wild Strawberry	2
Yellow Coneflower	4

After adding the proposed species, the number of total species increased from 30-37 and the native species increased from 28 to 35; the percentage of adventive species decreased from 6.7% to 5.4%; the FQI increased from 26.7 to 31.7 and FQI of native species increased from 27.6 to 32.6; the mean conservatism increased from 4.87 to 5.21 and mean conservatism of native species increased from 5.21 to 5.51(Table 28). Results indicate that new added species should support bee forage activities during the entire growing season and increase the floristic quality of the Meadowbrook Park community species composition.

Table 28. New Floristic Quality Assessment of Meadowbrook Park.

	Meadowbrook Park (existing)	Meadowbrook Park (proposed)
Total species richness	30	37
Native species richness	28	35
% Adventive (non-native)	6.70%	5.40%
Floristic Quality Index (FQI)	26.7	31.7
FQI (natives only)	27.6	32.6
Mean conservatism	4.87	5.21
Mean conservatism (natives only)	5.21	5.51

CHAPTER 6: CONCLUSION

It is important that agriculturalists and land managers take immediate steps to help pollinator populations thrive. Supporting pollinators' need for habitat also supports human needs for food and diversity in the natural world. Adding specific types of plants to landscapes that provide food and shelter for pollinators during their active seasons, and adopting pollinator-friendly landscape practices, can make a difference for both pollinators and people who rely upon them.

This study explored new strategies for combining campus land use and honeybee refuges by determining on the plant composition of existing No-Mow Zones and prairie zones on campus. Results show that both no-mow and prairie zones have the potential to support bee food sources, but based on bee habitat requirements, some species need to be added. Based on the existing plant composition and bee habitats requirements, I proposed three site designs focusing on two new sites, one existing No-Mow Zone and one enhancement plan for Meadowbrook Park. These proposed designs provide a framework to be used as a master plan and implemented over time.

Native plants provides year-round food for the honey bees, and attract a diversity of other pollinators and insects (Jeffords, 2014). Although feeding honey bees is the primary goal of this thesis, native bees can find refuge here as well. This thesis proposes bee habitat sites on campus, and envisions changes that could increase numbers of honey bees and native pollinators.

While this thesis focuses on the University of Illinois campus, it provides guidance for native prairie species selection to create new bee habitat and to enhance existing sites (e.g. No-Mow Zones, prairie zones). It also provides a demonstration and guidelines for land owners and farmers in Urbana-Champaign who wish to follow CP-42 Illinois guidelines. This design can be

extended beyond campus to networks of honeybee habitats across Illinois and across the United States.

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